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INTERDISCIPLINARY ENGINEERING CONVERGENCE FOR SUSTAINABLE INTELLIGENT FUTURES

INTERDISCIPLINARY ENGINEERING CONVERGENCE FOR SUSTAINABLE INTELLIGENT FUTURES



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FOREWORD



Shri. A. Srinivasan,
Chancellor, Dhanalakshmi Srinivasan University, TN, India

We stand at a defining moment in human advancement, where the frontiers of science and technology are expanding at an unprecedented pace. Each breakthrough not only redefines the boundaries of knowledge but also reshapes the cultural, economic, and ethical frameworks of our society. The real triumph of innovation, however, lies not in its novelty alone, but in its capacity to be wielded with wisdom, responsibility, and a vision for the greater good. The first edition of **Interdisciplinary Engineering Convergence For Sustainable Intelligent Futures** is a distinguished testament to the scholarly excellence of Dhanalakshmi Srinivasan Engineering College (Autonomous), Perambalur, Tamil Nadu. Encompassing **61** chapters traversing **Biological Sciences, Circuit Engineering, Non-Circuit Engineering, Software Engineering, and Management Studies**, this compendium exemplifies the transformative power of interdisciplinary inquiry. It illustrates how the synthesis of diverse perspectives can yield integrated, forward-looking solutions to the most pressing challenges of our age. I extend my sincere commendation to the Editors and contributors whose intellectual rigor and creative dedication have brought this work to fruition and to Publishers for their unwavering collaboration.It is my hope that this volume will not merely inspire but encouraging its readers to think beyond convention, to innovate with purpose, and to contribute meaningfully to a future where progress is measured not only by technological milestones but by the enduring benefit it imparts to humanity.

PREFACE

Research and innovation continue to transform the way we think, work, and create solutions for the future. With each passing year, the pace of discovery accelerates, making it vital to capture emerging ideas and present them in ways that inspire scholars and practitioners alike. It is in this spirit that we present the first edition of **Interdisciplinary Engineering Convergence For Sustainable Intelligent Futures**, highlighting the scholarly contributions of the faculty and researchers of Dhanalakshmi Srinivasan Engineering College (Autonomous), Perambalur, Tamil Nadu.

This edition is organized into five major domains—**Biological Sciences, Circuit Engineering, Non-Circuit Engineering, Software Engineering, and Management Studies—** reflecting both depth in individual disciplines and the richness of interdisciplinary collaboration. The chapters span a variety of fields, offering insights that link theory with practice and technology with societal needs.

We are deeply grateful to **Honourable Chancellor Shri. A. SrinivasanAyya, Chancellor, Dhanalakshmi Srinivasan University**, for his inspiring guidance. Our sincere appreciation also goes to the **Vice-chairman, Secretary, and the entire leadership of the Dhanalakshmi Srinivasan Group of Institutions** for their constant encouragement.

This volume is the result of the dedication of our authors, the careful efforts of the **Editorial Board.** Together, they have ensured that this first edition continues the tradition of excellence while opening new avenues of thought.

We hope this book will serve as a meaningful resource for students, researchers, and professionals, encouraging them to pursue innovation with responsibility and vision. Constructive feedback from readers will always guide us in shaping future editions.

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Biological Sciences

Chapter 1
STRUCTURE-GUIDED DISCOVERY OF HDAC6 INHIBITORS FROM SHOREA ROBUSTA FOR CARDIOVASCULAR DISEASE

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ABSTRACT

Histone deacetylase 6 (HDAC6), a unique cytoplasmic enzyme which has emerged as an important drug target in cardiovascular disease (CVDs) due to its role in regulating inflammation, protein homeostasis, fibrosis and oxidative stress within heart tissue. Selective inhibition of HDAC6 has shown the results in different preclinical models, including reduced heart muscle damage after injury, prevention of fibrosis, improved heart pumping function, reversal of maladaptive cardiac remodeling and even protection against endothermal dysfunction. While synthetic HDAC6 inhibitors are advancing, the medicinal plant, Shorea *robusta*, known for its antioxidant and anti-inflammatory properties and is also being considered as source of safer and new HDAC6 -targeting agents using structure guided approaches like docking against modeled HDAC6 domains, phytoconstituents from Shorea robusta are now screened for their ability to fit respective protein's active site and also block its activity which is relevant to heart disease, this helps to solve directions for both plant based and targeted cardio protective drug development.

KEYWORDS

Histone deacetylase 6, cardiovascular disease, Shorea robusta, phytoconstituents, Molecular docking

INTRODUCTION

Cardiovascular disease (CVDs) remains the leading cause of global morbidity and mortality and despite being a significant advances in clinical therapies and preventive care (Ranjbarvaziri et al.,2024). Cardiovascular disease which leads to traditional disease elements and disease particular categories (Ferguson et al., 2022). The need for novel therapeutic method is urgent especially those that specify the molecular mechanics driving CVDs. One emerging target of considerable interest is histone deacetylase 6 (HDAC6) -A CLASS IIb zinc dependent that gained

recognition for its pivotal role in cardiovascular pathophysiology (Ngo et al., 2022). Dysregulation of these pathways by overexpression or hyperactivation of HDAC6 has been implicated in several cardiovascular disorder, including myocardial infraction, cardiac fibrosis, hypertrophy, arrhythmia, pulmonary hypertension, and atherosclerosis (Wu et al., 2024). Unlike other HDAC isoforms that primarily function within the nucleus, HDAC6 is largely cytoplasmic, influencing a wide array of non-histone substrates that regulate cellular stress responses, protein degradation, inflammation, and fibrosis-all processes relevant to cardiovascular health (Zheng et al., 2025; Qu et al., 2025). The unique structural components of HDAC6, including two catalytic domain (CD1 and CD2) and a zinc finger ubiquitin-binding domain (ZNF-UBP), allowing it to combine with various protein targets (Liang et al., 2025; Jo et al., 2022). These include α-tubulin, HSP90, Cortactin, and Prdx1, influencing cellular cytoskeletal dynamics, chaperon function, redox homeostasis, and misfolded protein clearance (Kovacs et al., 2005; Du et al., 2021; Kawaguchi et al., 2003). From a drug design perspective, HDAC6 is particularly noteworthy. Most of the HDAC6 inhibitors go after a wide range of targets, which may often mean they brings a too much of side effects and even toxicity, just too much collateral damage. But when you zero in on HDAC6, you can actually protect the heart without messing up the whole system (Shelley et al., 2024). Preclinical studies back this up: targeting HDAC6 helps lessen damage from myocardial ischemia-reperfusion, keeps fibrotic genes in check, slows down harmful changes in the ventricles, and even helps blood vessels work better (Yu-Jen Wang et al., 2024). For instance, HDAC6 inhibitors such as ACY-1215 and Trichostatin A have shown efficacy in reducing infarct size, improving cardiac output, and preventing atrial fibrillation by stabilizing microtube structures and improving calcium homeostasis in cardiomyocytes (Kundu et al., 2024; Qu et al., 2025). HDAC6 steps in as a major player when it comes to control of inflammation and fibrotic responses, working through downstream effectors like TGF-β, ERK1/2, and MeCP2. These will derive cardiac fibrosis and hypertrophy classic signs of ongoing heart damage (Zheng et al., 2025 and Birindisi et al., 2019). When you block HDAC6, you ramp up anti-fibrotic signals like RASSF1A and dial down fibroblast activation. It's a pretty targeted way to keep the heart from remodeling itself in all the wrong ways (Tao et al., 2016),Probably in cardiovascular diseases like atherosclerosis, which inhibiting HDAC6, which have combined to better endothelial function, lower oxidative stress, and reduced production of pro-inflammatory cytokines ,this will helps slow the biofilm development and Arterial Stiffening (Nomura et al., 2021). The current range of HDAC6 inhibitors includes hydroxamic acids like Vorinostat and Trichostatin A, along with benzamides such as entinostat and short-chain fatty acids like valproic acid (Wang et al., 2018). A lot of HDAC inhibitors hit multiple targets, but now researchers are zeroing in on crafting drugs that go after HDAC6 specifically. They have been

being used a structure-based drug design to find molecules that fit snugly into both the enzyme's active site and its ubiquitin binding pocket (Lee et al., 2013; Zhu et al., 2023). This kind of precision matters-a more selective inhibitor means fewer side effects. It's not just about hitting the right target, because HDAC6 works in the cytoplasm, any drug aiming at it needs to move efficiently inside cells and stick around long enough to do its job (Lee et al., 2013; Marks et al., 2013). As scientists learned more about this and how HDAC6 plays into heart disease-especially through the epigenetic changes and unique protein interactions they're building a solid case for targeting it in new therapies (Berdasco et al., 2013 and Puya et al., 2021). By mixing computational modeling with high-throughput screening and rigorous lab tests, the field is pushing toward HDAC6 inhibitors tailored for heart problems. These drug might work on their own, but there's also a real promise in combining them with current heart or cancer treatments and boosting effectiveness and which cutting down on heart-related side effects (Yang et al., 2022) *Shorea Robusta*, also known as sal tree and referred to as Kungiliyam in siddha medicine, is a multi-therapeutic plant widely recognized in traditional systems like ayurveda and sidda for its resin, leaves, and bark, which possess potent medical properties. Research shows *Shorea robusta* exhibits analgesic, anti-inflammatory, immunomodulatory, wound healing, antimicrobial, antioxidant and anticancer activities (Musa et al., 2023). The resin obtained from the plant is considered as an astringent and a detergent and is used with honey or sugar in dysentery and bleeding piles and also for fumigating the rooms of ill people. It is also given in gonorrhea and for a week digestion. Its bark decoction is used as drops for ear problems and the fruits for diarrhea. *S.robusta* leaf extract was found to possess significant analgesic activity and its resin along with some other constituents has also shown potential in wound healing (Chatterjee et al., 2019; Jyothi et al., 1996).

Shorea robusta is native to the Indian subcontinent, specifically found in countries such as India, Nepal, Myanmar. Scientific studies have validated these traditional uses, demonstrating *Shorea robust's* analgesic activity by prolonged reaction time in animal pain models and its anti-inflammatory actions through inhibition of pro-inflammatory cytokines such as TNF-α, IL-1β AND IL-6. *Shorea robusta* is a large, deciduous tree up to 50 m tall and with a dbh of 5m, these are exceptional sizes, and under normal conditions *S. robusta* trees attain a height of about 18-32 m and griths of 1.5-2m; straight and cylindrical , but often bearing branches; crown is spreading and spherical (Debprasad et al., 2012 and Ito et al., 2013).HDAC6 inhibitors can alter important pathways involved in cardiac function and pathology, they have demonstrated the treatment of cardiovascular disease through molecular docking, there is a little specific evidence for herb inhibitors which is derived from *Shorea robusta* (kungiliam) in the reviewed literature and despite recent research by virtual screening and molecular docking to identify specific inhibitors

(Drakontaeidi et al., 2023). Inhibition of HDAC6 in cardiovascular disease by lowering the oxidative stress and minimizing tissue damage following myocardial injury, HDAC6 inhibition enhances cardiac function and may help prevent heart failure and hypertrophy by affecting pathways such as Prdx1 acetylation and COX2/PGE2. By affecting the contraction of vascular smooth muscles cells, HDAC6 inhibition has also been linked to decreased cardiac fibrosis and better blood pressure regulation (Wu et al., 2024).



Fig.1(a). HDAC6 Protein structure

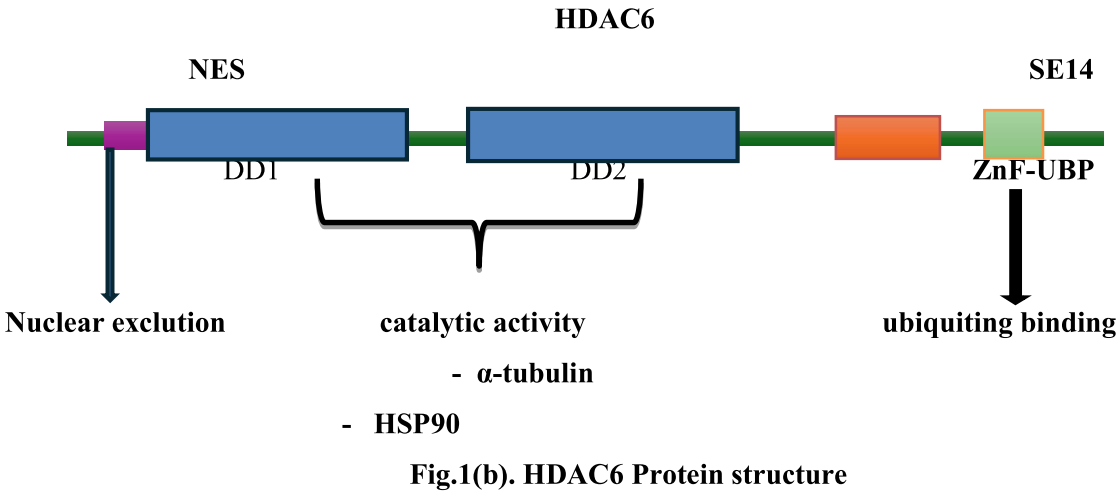


Fig.1(b). HDAC6 Protein structure

FEATURE	DESCRIPTION
Protein Name	HDAC6
Amino Acids	1215 amino acids
Protein class	Class IIb histone deacetylase
Catalytic Domains	Two tandem catalytic domains 9CDIIb and CD2)
Ubiquitin Binding	ZnF-UBP
Substrates	α-tubulin, HSP90, cortactin, Foxp3

Table 1: **HDAC6 Protein structure**

METHODS OF MOLECULAR DOCKING

Crystallographic HDAC6 structures like, PDB:5EDU are used in molecular docking studies to examine the binding modes of possible inhibitors ,with a focus on coordination with zinc ion cofactor of enzyme and polar interactions like hydrogen bond (Porter et al., 2017).Using reference molecules such as Trichostatin A(TSA) as benchmark ,docking simulation have demonstrated the significance of hydrophobic interactions and electrostatic complementarities between candidate molecules and activate site residues .Although ,majority of successfully docked candidates have come from general compound screens rather than specifically from Shorea robusta ,some of the studies have used pharma core models derived from herb compounds databases (Narayanan S et al., 2013).

***Shorea Robusta's* Relevance**:

The use of *Shorea robusta* compounds as HDAC6 inhibitors for cardiovascular applications is not yet supported by direct evidence or results from some published molecular docking reviews, if future research isolates and virtually screens *Shorea robusta* phytoconstituents against HDAC6, docking methodologies will still be a useful method for assessing these compounds.

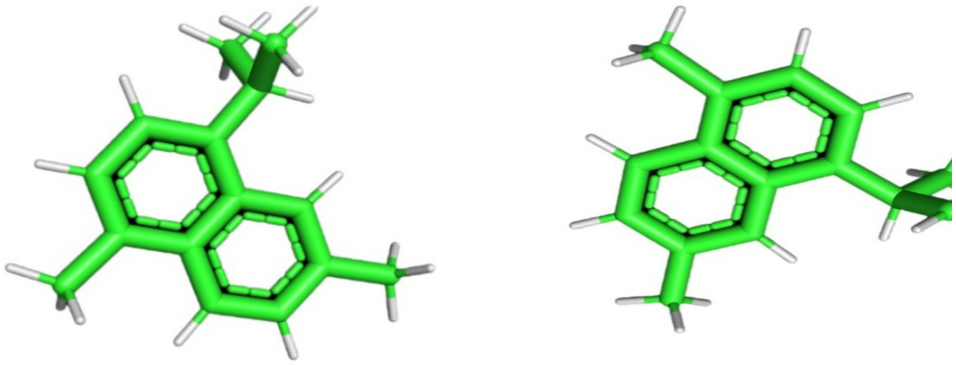


Figure 2: Ligand Structure of *Shorea Robusta*

FEATURES	RESLTS
Therapeutic outcome	Anti-fibrosis, cardioprotective (Wu et al., 2024)
Docking interactions	Coordination, hydrogen bonding (Drakontaeidi et al., 2023)
Reference substance	Trichostatin A, Virtual screening (Drakontaeidi et al., 2023)
Shorea robusta evidence	Specifically not mentioned in recent reviews

Table 2: Features of *Shorea robusta*

ATTRIBUTE	NUMERICAL RANGE /
Typical height	18 – 32 m
Maximum height	Up to 40 -50 m
Typical truck diameter	1.5 -2.5 m
Leaf length	10 – 25 cm
Leaf breadth	5 – 15 cm

Table 3: Some of the Crucial Results from HDAC6 Docking Literature

MODELING USING SWISS-MODEL

Homology modelling of human HDAC6 catalytic domain (CD1 AND CD2) was performed using the SWISS-MODEL webserver, which provides an automated environment for template-based protein structure prediction, the modelling workflow involves template identification, sequence alignment, model construction, and quality evaluation. The program uses promod3 as the modelling engine to transfer conserved atomic coordinates, reconstruct loops, model insertions and deletion and rebuild side chains within the open structure framework (waterhouse et al., 2018).

SWISS-MODEL offers three operational modes, which automatically searches for suitable templates; alignment mode, which uses user-supplied alignments: and project mode, which allows manual manual adjustment of templates (Arnold et al., 2006). The SWISS-MODEL template library (SMTL) integrates experimentally determined structures from the protein data bank (PDB) and is updated weekly to ensure coverage of newly released templates. Template selection is based on global model Quality estimation (GMQE), Quaternary structure quality estimate (QSQE),and sequence identify, with coverage below 50 percent generally considered inadequate for reliable model generation (Bienert et al ., 2017) .For HDAC6, missing residues with the crystal structure (PDB ID: 5EDU) were reconstructed using SWISS-MODEL to produce a complete structural model for downstream docking experiments (Xu et al., 2022).

VIRTUAL SCREENING USING AUTODOCK VINA

Virtual screening targeted the CD2 domain of HDAC6 to identify active phytochemical Derived from a siddha polyherbal formulation .A total of 329 phytochemicals were retrieved from the IMMPAT 2.0 database for docking (Mohanraj et al., 2018). Docking was performed using Auto Dock Vina , which employs an efficient scoring function and gradient-based optimization algorithm to predict ligand binding affinities (Trott O et al., 2010). The docking grid was set with box dimensions of 21 x 24 x 20 Å and centered at coordinates x = -2.91, y =9.517 and z = 11.593 Å. It allowed six docking poses per ligand and used a screening configuration that ensured thorough sampling of the active site residues involved binding to the HDAC6 CD2 domain (Liu et al., 2025).

MOLECULAR DOCKING VIA AUTODOCK

To refine the binding conformation and scoring accuracy, molecular docking was repeated using AutoDock 4.2 with the Lamarckian Genetic Algorithm. The receptor and ligand files were prepared using AutoDock Tools (ADT) 1.5.7 following standard docking protocols to assign

Gasteiger charges and define torsional bonds. Each ligand was subjected to 100 LGA runs to ensure adequate conformational sampling and convergence of docking scores (Morris et al., 2009). The top five phytochemicals showing the highest negative binding energies were shortlisted for interaction visualization using UCSF chimere (Pettersen et al., 2004) and hydrogen bond mapping in ligplus (Wallace et al., 1995)

MOLECULAR DYNAMICS (MD) SIMULATION

Molecular dynamics simulations for HDAC6-phytochemical complex and the apo form were carried out using GROMACS 2024.4 with the CHARMM36 all-atom force field (Abraham et al., 2015; Huang et al., 2013). Ligand topology files were generated using the CGenFF server to maintain compatibility with the CHARMM force field (Vanommeslaeghe et al., 2010). Each system was immersed in a cubic water box with 1 nm buffer using the SPC model and neutralized with counterions (Berendsen et al., 1981). Energy minimization was achieved using the steepest descent algorithm, followed by equilibration under NVT and NPT ensembles at 300 K and 1 bar, respectively, for 100 ps each (Berendsen et al., 1984). Production MD simulations were performed for 1 ns with trajectory frames saved every 10 ps. Post-simulation structural analysis, including root mean square deviation (RMSD), root mean square fluctuation (RMSF), Radius of gyration (Rg), and hydrogen bond count, were carried out to assess complex stability using the XMGrace plotting tool (Berendsen et al., 1984).

METHODOLOGY

Target and ligand preparation

Thinking of the HDAC6 protein is considered as a lock and potential inhibitors as keys. First, get a detailed 3D image of the lock (HDAC6) from the database. Then, get a detailed 3D image of the lock (HDAC6) from the database. Then, prepare the keys (ligands), making sure they are properly shaped and suitable for further testing. This setup is essential for reliable simulations later (Mirsha et al., 2022).

Molecular docking

Here, try to fit each key into the lock virtually to see which fits best. Docking predicts how well the ligand bind the position it takes inside the HDAC6 active site, helping you pick promising candidates for deeper analysis (Shamsi et al,. 2024).

1.Protein and ligand preparation

The main protein to be worked with (HDAC6) is getting ready and the water molecules are removed unless they are essential. The missing parts of the protein structure are reconstructed, and

all the changes that have be made are analysed to assure that they are collect and the molecule has been optimized at the target condition. Ligands, which are the compounds that are believed to inhibit the target and derived from various sources, undergo a process of energy minimization and are then assigned the correct form of ionization as active ligands for docking (Meng et al., 2011).

2. Active Site Identification and Grid Generation

The protein's binding pocket is recognized mainly by known residues of the active site or by the co-crystallized ligands. For the purpose of making the docking calculations in the relevant area and thus making the process more efficient and less-time consuming, a computational grid or box is made around this site (Agu et al., 2023).

3. Conformational Sampling (Docking Execution)

Docking of the molecules is done through the use of computational algorithms that try different shapes and placements for the ligands within the binding area. The different ways in which the ligands can be placed are separating the ligand from the protein and treating the protein as a rigid entity, or giving the protein some flexibility and finding the optimal configuration through the "induced-fit" method. All these approaches yield multiple binding poses for a given ligand (Meng et al., 2011).

4. Scoring and Ranking

Each docked pose is subjected to scoring functions that estimate binding affinity by taking into account different types of interactions between the ligand and the target, the main ones being hydrophobic contacts, the presence and number of hydrogen bonds, electrostatics, and sterics. Consequently, ligands are classified according to their scores, and the compounds with the highest scores are chosen for subsequent studies. Lower docking scores indicate better predicted binding affinities (Shamsi et al., 2024).

System setup for MD

Solvation with explicit water and adding ions for neutralization and mimicking physiological salt concentration are normally done, as described in the same molecular dynamics preparation of the system for realistic simulation. Solvation with explicit water and adding ions for neutralization and mimicking physiological salt concentrations are normally done, as described in the same molecular dynamics preparation of the system for realistic simulations (Mishra et al., 2022).

Energy Minimization

The initial system may have unfavorable contacts, energy minimization relaxes these by algorithmically adjusting atom position to local energy minima, preventing structural clashes that could destabilize the simulation. The process of relaxing the steric clashes in the initial complexes by minimizing the energy, followed by equilibration, is one of the basic steps (Mishra et al., 2022).

Equilibration

The pressure and temperature are then equilibrated using isothermal-isoberic ensemble conditions, which allows water and ions to equilibrate around the protein-ligand complex (Shamsi et al,. 2024).

Production MD Simulation

Extensive MD simulation (hundreds of nanoseconds) to observe the dynamics nd binding stability in HDAC6-ligand complexes are exemplified and which tracked conformational changes over time (Mishra et al., 2022).

Trajectory Analysis

Analysis metrics, such as RMASD, RMSF, hydrogen bonds, and radius of gyration, during HDAC6-inhibitor simulation come from both studying stability of the complex and the fluctuation of residues (Mishra et al., 2022).

Binding Free Energy Calculation

MM/GBSA calculation for the quantification of binding free energy has appeared in quantitative ranking the efficacy of ligand against HDAC6 (Mishra et al., 2022).

Residue Decomposition

Energy contribution analysis per residue, highlighting important active site amino acids in the binding analysis section of lends insight into functional groups critical for inhibition (Mishra et al., 2022).

APPLICATIONS IN CARDIOVASCULAR DISEASE

Structure guided discovery of HDAC6 inhibitors, particularly using compounds derived from *Shorea robusta* which holds significant promise for cardiovascular disease therapy due to the key regulatory roles HDAC6 plays in cardiac pathology and vascular health.

1. Improvement in cardiac function and reduction of reactive oxygen species after ischemia /reperfusion injury.

2.Decreased cardiac fibroblast proliferation and fibrosis.

3.Protection against cardiac hypertrophy and arrhythmia.

4.Prevention of atherosclerosis and greater endothelial health by modulating inflammatory and fibrotic pathways.

CONCLUSION

This paper finding the new medicines by structure guided discovery of HDAC6 inhibitors from a plant, *Shorea robusta* and their potential in treating cardiovascular disease (CVDs) and their conditions driven by fibrosis, inflammation and etc. HDAC6 is a cytoplasmic enzyme implicated in a maladaptive cardiac remodeling via pointed disease and making it appealing selective therapeutic

target. Utilizing computational methods like docking platforms and crystallographic data, phytochemicals from *Shorea robusta* were screened for their binding affinity of HDAC6's catalytic and ubiquitin -interacting domains and Trichostatin A served as a positive control in assays, allowing benchmarking the efficacy of *Shorea robusta* - derived HDAC6 inhibitors. Then the HDAC6 inhibitors show potential for treating cardiovascular disease by reducing heart damage prevents fibrosis and improve cardiac function. HDAC6 is highlighted as a unique class IIb, zinc-dependent, predominantly cytoplasmic deacetylase with two catalytic domains (CD1,CD2) and a zinc finger ubiquitin binding (znF-UBP) (ubiquitin binding domain) enabling a regulation of non-histone substrate like α-tubulin, HSP90, cortactin and prdx1 which will control cytoskeletal dynamics and inflammatory signaling in the heart. Overall, this paper proposes concept driven, methodology focused work that integrates cardiovascular HDAC6 biology and *Shorea robusta* pharmacological profile and modern computational tools to justify future structure guided discovery of plant based HDAC6 inhibitors for CVD therapies and validation in specific plant target axes.

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Chapter 2

MEDSECURE BIOMETRIC RECORD SYSTEM WITH QR CODE PRESCRIPTION

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ABSTRACT

In today's rapidly evolving healthcare environment, managing patient data has become increasingly challenging due to rising concerns over security, accessibility, and workflow efficiency. To address these issues, this project introduces a secure and innovative solution: The Fingerprint Authentication-Based Patient Database Management System (FAPDMS). The system utilizes unique biometric fingerprint patterns to authenticate users, providing a more secure and reliable method for accessing sensitive patient information. The FAPDMS architecture is composed of three major components: fingerprint enrollment, secure database management, and real-time biometric authentication. During enrollment, the system captures and stores the unique fingerprint patterns of patients and healthcare professionals, eliminating reliance on traditional authentication such as passwords or PINs. The encrypted central database ensures that medical records are protected and accessible only to authorized users. Real-time biometric verification allows healthcare professionals to instantly access patient information during consultations, improving decision-making and streamlining clinicalworkflows.

KEYWORDS:

Patient data management, Security, Biometric authentication, FAPDMS, Healthcare efficiency, Real-time access

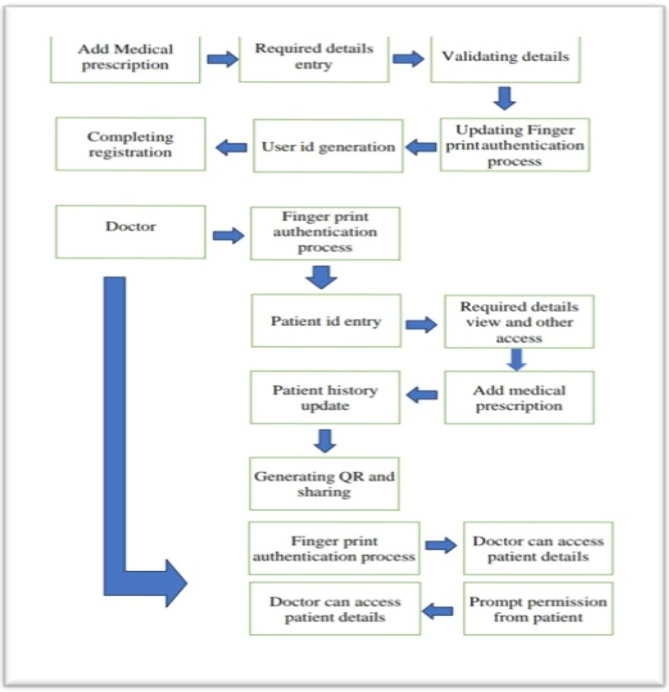
INTRODUCTION

In the digital era, the healthcare sector is witnessing a paradigm shift in the way patient data is managed and accessed. With the proliferation of electronic Health records (EHRs) and the increasing reliance on digital platforms for healthcare delivery, the importance of robust data security measures cannot be overstated. The safeguarding of patient information against unauthorized access, breaches, and data theft has emerged as a paramount concern for healthcare providers worldwide.

Traditional methods of user authentication, such as passwords and personal identification numbers (PINs), have proven to be vulnerable to security threats, including password theft, brute force attacks, and social engineering exploits. Consequently, there is a growing need for innovative authentication solutions that offer enhanced security, reliability, and user convenience. In response to these challenges, this project introduces a Fingerprint Authentication-Based Patient Database Management System (FAPDMS). FAPDMS represents a pioneering approach to healthcare data security, leveraging fingerprint biometrics as a means of user authentication and access control. By harnessing the unique physiological characteristics of fingerprints, FAPDMS offers a robust and reliable method for verifying the identity of users, thereby minimizing the risk of unauthorized access to sensitive patient information.

The primary objective of FAPDMS is to address the shortcomings of traditional authentication methods while streamlining the process of patient data management in healthcare settings. By integrating fingerprint authentication with a comprehensive database management system, FAPDMS aims to enhance the Security, efficiency, and accessibility of patient records, ultimately improving the quality of healthcare delivery. This introduction sets the stage for a detailed exploration of FAPDMS, including its underlying principles, system architecture, key features, and potential benefits for healthcare providers and patients alike. Through empirical testing and analysis, this project seeks to evaluate the effectiveness and feasibility of FAPDMS as a viable solution for addressing the evolving security challenges in healthcare data management.

MATERIALS AND METHODS



A redesigned system for handling patient records and prescription details would involve creating a secure, centralized database accessible through fingerprint-based authentication rather than traditional passwords. This database would store comprehensive patient information, including medical history, allergies, demographic details, test results, consultation documents, and prescription records. The system would include an intuitive interface featuring tabs for functionalities such as patient registration and medication recommendations. The patient registration module would allow healthcare providers to enter and update patient details efficiently, ensuring accurate and easily retrievable records. The interface is designed to minimize typing effort and reduce input errors by offering intelligent suggestions, supported by a decision tree model.

The proposed Fingerprint Authentication-Based Patient Database Management System (FAPDMS) aims to transform the manner in which healthcare facilities manage and access patient data. It utilizes advanced fingerprint biometric technology to improve security, operational efficiency, and accessibility. The system includes the following key components:

1.Fingerprint Enrollment Module:

- Fingerprint scanners capture an image of a person's fingerprint and then compare it to a database of known fingerprints. If the fingerprint matches a known fingerprint, the person is authenticated. Fingerprint scanners are used in various devices, including laptops, smartphones, and tablets.
- Capacitive or CMOS scanners use capacitors and thus electric current to form an image of the fingerprint. This type of scanner tends to excel in terms of precision. Ultrasonic fingerprint scanners use high frequency sound waves to penetrate the epidermal (outer) layer of the skin.
- Users, including healthcare professionals and patients, will be enrolled in the System by capturing their fingerprints using biometric scanners.
- Fingerprint templates will be generated and securely stored in the system's database as unique identifiers for each user.

2.Authentication and Access Control Module:

- FAPDMS will utilize fingerprint biometrics for user authentication, allowing authorized users to securely access patient records.
- Upon authentication, users will be granted access to specific functionalities and patient data based on their roles and permissions.

3.Secure Database Management:

- Patient records, including medical history, diagnostic reports, and treatment Plans, will be stored in a centralized database.
- The database will be encrypted to ensure the confidentiality and integrity of patient data, with access restricted to authorized users.

4. User Interface:

- FAPDMS will feature an intuitive user interface designed to streamline the navigation and interaction with the system.
- Healthcare professionals will be able to easily search, retrieve, update, and analyze patient records, facilitating informed decision-making and efficient patient care delivery.

5. Real-Time Updates and Alerts:

- The system will support real-time updates to patient records, allowing healthcare professionals to access the most current information during consultations and treatments.

6. Integration and Interoperability:

- FAPDMS will be designed to integrate seamlessly with existing healthcare information systems, electronic health records (EHRs), and medical devices.
- Interoperability standards such as HL7 (Health Level Seven) will be followed to facilitate data exchange and interoperability with external systems.

7. Scalability and Future Enhancements:

- The proposed system will be scalable to accommodate the evolving needs and growth of healthcare facilities.
- Future enhancements may include the integration of advanced analytics, artificial intelligence (AI), and blockchain technology to further enhance system capabilities and security.

SOFTWARE DESCRIPTION

WEB APPLICATION

A web application is a software program that runs on a remote server and is accessed by users through a web browser over the Internet. Unlike traditional desktop applications, a web application does not require installation on the user's device; instead, all processing and data management take place on the server. When a user performs an action such as clicking the "Read More" button or submitting a form, the browser sends a request to the web application server, which then processes the request and sends back the appropriate response. Web applications are platform-independent, meaning they can run on any device with an internet connection and a browser. They typically integrate with databases to store and retrieve information, making them suitable for services like social media, online banking, e-commerce, and educational portals. With centralized updates, enhanced security features, and interactive user interfaces supported by technologies like HTML, CSS, JavaScript, and modern frameworks, web applications have become an essential part of today's digital ecosystem.

MIT APP

MIT App Inventor is an innovative, cloud-based visual programming environment designed to simplify mobile application development for beginners and non-programmers. Developed originally by Google and now maintained by the Massachusetts Institute of Technology (MIT), it enables users to create fully functional Android and iOS applications using an intuitive block-based programming concept. Instead of writing lengthy code, users can drag and drop visual components in the Designer interface and define their behavior using logic blocks in the Blocks editor. This block-based system eliminates syntax errors and promotes logical thinking, making it an ideal platform for students learning computational thinking, problem-solving, and app development concepts.

The platform includes a wide range of built-in components, such as user interface elements, sensors (accelerometer, gyroscope, GPS), multimedia tools (camera, sound recorder, video player), and connectivity modules like Bluetooth, Wi-Fi, Web API, and Firebase integration. These components allow learners to build advanced applications such as health monitoring systems, IoT-based home automation, quiz apps, location trackers, and educational tools. App Inventor also supports real-time testing through the AI2 Companion App, which instantly reflects changes on a connected mobile device, making the development process interactive and engaging.

A key strength of MIT App Inventor is its accessibility—users only need a browser and internet connection, with projects stored securely in the cloud. The platform is widely used in schools, colleges, innovation labs, and coding workshops across the world to introduce programming concepts in a simple and enjoyable way. With support for exporting APK files, sharing projects, and even publishing apps to the Google Play Store, MIT App Inventor empowers learners to transform their ideas into real, working mobile applications. Today, it serves over a million users annually and remains one of the most influential educational tools for teaching mobile app development and computational thinking. The Fingerprint Authentication-Based Patient Database Management system (FAPDMS) proposed in this project holds immense potential for revolutionizing healthcare data management across various applications. Some key applications of FAPDMS include:

1.Hospitals and Healthcare Facilities:

FAPDMS can be implemented in hospitals, clinics, and other healthcare facilities to streamline patient data management processes. Healthcare professionals can securely access patient records in real-time using their fingerprints, facilitating prompt and informed decision-making during consultations, treatments, and emergencies.

2.Electronic Health Records (EHRs):

FAPDMS can integrate seamlessly with electronic health record (HER) systems, enhancing the security and accessibility of patient health information. By replacing traditional authentication

methods with fingerprint biometrics, FAPDMS mitigates the risk of unauthorized access to sensitive medical data, ensuring compliance with stringent privacy regulations such as HIPAA.

3.Telemedicine and Remote Healthcare:

In the era of telemedicine and remote healthcare delivery, FAPDMS enables secure access to patient records from remote locations. Healthcare providers can authenticate themselves using their fingerprints, allowing them to access and update patient information securely, regardless of their physical location. This capability enhances the efficiency and effectiveness of telemedicine consultations while maintaining data security and confidentiality.

4.Pharmaceutical Industry:

FAPDMS can also find applications in pharmaceutical companies and research institutions involved in clinical trials and drug development. By providing Secure access to patient data, FAPDMS facilitates the management of clinical trial participants' information, ensuring compliance with regulatory requirements and safeguarding the integrity of research data.

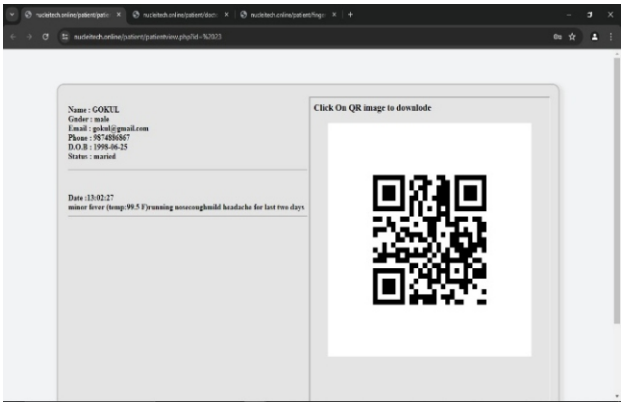
RESULTS AND DISCUSSION

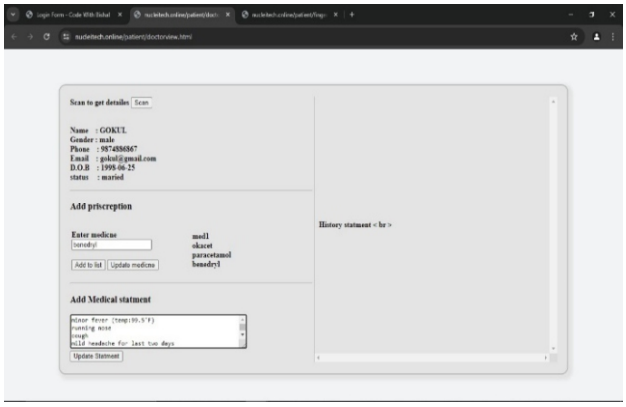
The implementation and testing of the Fingerprint Authentication-Based Patient database Management System (FAPDMS) have yielded promising results, demonstrating its effectiveness in enhancing healthcare data security and accessibility. Through rigorous testing and evaluation, the following key findings have emerged:

1.Enhanced Security: FAPDMS has significantly strengthened data security by replacing traditional authentication methods with fingerprint biometrics. The system's robust authentication protocols have successfully mitigated the risk of unauthorized access to patient records, ensuring compliance with stringent privacy regulations.

2.Improved Efficiency: FAPDMS has streamlined the process of accessing and managing patient records, resulting in improved efficiency and workflow Optimization within healthcare settings. Healthcare professionals can retrieve patient information swiftly during consultations and treatments, facilitating more informed decision-making and enhancing patient care quality.

3.User Acceptance: Feedback from healthcare professionals involved in the testing phase indicates high levels of satisfaction with FAPDMS's user interface and authentication process. The system's intuitive design and seamless integration into existing workflows have contributed to positive user experiences and acceptance among healthcare staff.





CONCLUSION

The proposed Fingerprint Authentication-Based Patient Database Management System (FAPDMS) successfully demonstrates a secure, efficient, and modern approach to healthcare data management. By replacing traditional password-based access with biometric authentication, the system significantly enhances data security and reduces the risk of unauthorized access to sensitive patient records. The centralized, encrypted database and intuitive user interface improve workflow efficiency, enabling healthcare professionals to access and update patient information quickly and accurately. Testing results confirm strong user acceptance, improved accessibility, and reliable performance across various scenarios. Overall, FAPDMS offers a practical and scalable solution for hospitals, telemedicine platforms, and healthcare institutions, marking an important step toward safer, smarter, and more streamlined digital healthcare management.

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Chapter 3
DETECTION OF DIABETIC RETINOPATHY USING MACHINE LEARNING METHODOLOGY

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ABSTRACT

If left untreated, diabetic retinopathy, a condition brought on by uncontrolled chronic diabetes, can result in total blindness. Therefore, in order to avoid the serious side effects of diabetic retinopathy, early medical diagnosis and treatment are crucial. Patients must endure a great deal of suffering during the lengthy process of an ophthalmologist manually diagnosing diabetic retinopathy. Diabetic retinopathy can be promptly detected by an automated system, and treatment can be readily followed up on to prevent additional eye damage. This study suggests a machine learning technique for classifying and extracting three features—exudates, hemorrhages, and microaneurysms—using a hybrid classifier that combines logistic regression, support vector machines, k nearest neighbors, random forests, and multilayer perceptron's.

KEYWORDS

Diabetic Retinopathy, Machine Learning, Feature Extraction, Hybrid Classifier

INTRODUCTION

One consequence of high blood glucose, known as diabetes, that affects the eye is diabetic retinopathy. It can result in vision loss and, in extreme cases, total blindness. Eye floaters, darker patches of vision, blurred vision, and trouble seeing color are some of the early signs of diabetic retinopathy. To avoid total blindness, diabetic retinopathy must be properly detected in its early stages. Approximately one-third of the 285 million people with diabetes mellitus worldwide exhibit symptoms of diabetic retinopathy. By 2030, there will be 191.0 million diabetic retinopathy sufferers worldwide, up from 126.6 million in 2010. Tiny red spots appear in the retina during the early stages of non-proliferative diabetic retinopathy (NPDR).

LITERATURE REVIEW

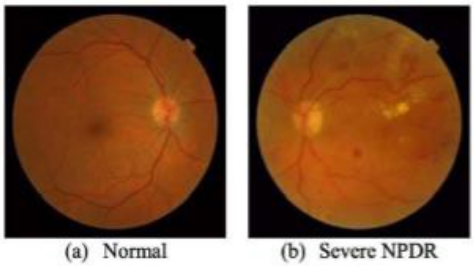
Diabetic retinopathy (DR) is a major complication of diabetes and a leading cause of blindness worldwide. Early detection is critical for preventing vision loss, but traditional manual diagnosis of retinal fundus images is time-consuming and subject to human error. This has led to increasing interest in automated detection using machine learning (ML) techniques. Early approaches focused on classical ML algorithms. SVMs, k-Nearest Neighbors (KNN), and Random Forests have been widely applied to classify retinal images based on extracted features such as microaneurysms, hemorrhages, and exudates. Farrikh Alzami et al. (2019) used fractal analysis combined with Random Forest to classify DR grades with promising accuracy [1]. Similarly, Gulshan et al. (2016) developed a deep learning-based algorithm that outperformed classical approaches in both sensitivity and specificity for DR detection [2].

Deep learning techniques, particularly Convolutional Neural Networks (CNNs), have shown superior performance by automatically extracting features from fundus images. Pratt et al. (2016) implemented CNNs to classify DR and demonstrated improved detection of early-stage abnormalities [3]. Quellec et al. (2017) proposed a deep image mining framework that enhances lesion detection in fundus images, improving overall DR screening performance [4].Hybrid and ensemble methods have also gained attention. Aushik et al. (2021) combined multiple deep learning models in a stacked generalization framework, improving classification accuracy on small datasets [5]. Mohanty et al. (2023) applied deep CNN architectures along with preprocessing techniques to enhance DR detection, showing the effectiveness of combining feature extraction and classification approaches [6]. Abramoff et al. (2018) demonstrated the clinical applicability of autonomous AI-based systems for DR detection, emphasizing the importance of integrating automated ML systems into real-world screening [7].
Despite these advancements, challenges remain, including data imbalance, limited annotated datasets, and model interpretability. Hybrid approaches that combine classical ML algorithms like SVM, KNN, and Random Forest have shown promise in addressing these challenges, particularly for medium-sized datasets with carefully extracted features. The present study builds on these works by implementing a hybrid classifier framework to improve accuracy and robustness in DR detectio.

DATASET

The Kaggle dataset for diabetic retinopathy detection was made publicly available for this work. The database was constructed using pictures from retinopathy detection datasets that were made publically available. One thousand photos with diabetic retinopathy and one thousand without are included in the Kaggle dataset.Out of all the photos, we selected 122 with diabetic retinopathy and 122 without. The selected aberrant images show microaneurysms, hemorrhages, and exudates. The

appearance, quantity, size, and distribution of exudates, microaneurysms, and hemorrhages, as depicted in Figure 1, are indicators of the presence of diabetic retinopathy.The yellowish-looking, bright patches that differ slightly in color from the optic disc are called exudates. Exudates are produced by the lipid-containing burst blood artery.



(a) Normal (b) Severe NPDR

The first step in image pre-processing is to transform the dataset image to an HSV image in order to identify exudates. Converting a picture represented in one color space to another with the intention of making the translated image resemble the original as much as feasible is known as color space conversion. The provided image's red, blue, and green channels correspond to hue, saturation, and value. When converting RGB to HSV, it is helpful to separate yellow-colored exudates from the RGB image.Next, adaptive histogram equalization, median filtering, and edge zero padding are carried out.technique wherein a small "image piece" is defined and used to alter a bigger image. Here, we are using blue ([0,0,0255]) to mask the optic disc and yellow ([60,255,255]) exudates in the smoothed image. The hybrid classifier is being implemented in the suggested approach. That is, we are utilizing a mix of five classifiers, including Random Forest, K closest neighbors, Support Vector Machines, and others. The 244 photos will be divided into normal and pathological categories by each classifier. The SVM classifier is employed using a degree 3 kernel radial bias function. Once we had the classifiers, we used a hybrid voting process. Five distinct classifiers are used to train the dataset, then testing is conducted. The ratio of training to testing sets is 80:20.The supervised machine learning method known as Support Vector Machine (SVM) is widely utilized for everyday issues including regression and classification. It is primarily applied to classification problems as opposed to regression difficulties. We will use the SVM method to KNN

Voting is the most straightforward way to aggregate the results of several machine learning algorithms. Using our training dataset, we first develop two or more independent machine learning models. When a new set of data is fed into the model for prediction, our standalone models can then be combined using a voting classifier, which will then average the predictions of the standalone sub-models. Weighting the sub-models' predictions can be done heuristically or manually by assigning a weight to each model.

RESULTS AND DISCUSSION

The ability of a test to accurately identify individuals who have a disease is known as sensitivity. TP divided by (TP + FN) is sensitivity. The ability of a test to accurately rule out individuals who do not have a disease condition is known as specificity. TN divided by (TN + FP) is specificity. When a test result is positive and a person is able to identify the illness, this is known as a true positive (TP). When a test is negative and a person is not given a disease diagnosis, this is known as a true negative (TN). When a test result is positive but the person is unable to communicate it, it is known as a false positive (FP). A false negative (FN) occurs when a person receives a negative result. 68% accuracy is achieved with SVM. The random forest achieves 90% and the KNN classifier 76%.

CONCLUSION

This suggested approach detects microaneurysms, exudates, and hemorrhages. Bitwise AND, masking, smoothing, and green channel extraction are used for exudate detection, which improves exudate extraction and calculation. Using morphological procedures like opening, hemorrhages and microaneurysms can be found. Here, operators for erosion and dilation are used. Counting the number of MA events, hemorrhages, and exudates in the image allows us to determine the image's condition and detect diabetic retinopathy. Following calculation, features are fed into the Random Forest, KNN, and SVM classifiers. The final prediction is determined by voting among three classifiers. Therefore, the disease grade is immediately determined as Normal or Abnormal based

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Chapter 4

DETECTION OF BLOOD GROUP USING IMAGE PROCESSING AND DEEP LEARNING

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ABSTRACT

This project proposes a contactless blood group detection system using fingerprint images and deep learning. It involves preprocessing , data augmentation, and InceptionV3 model for feature extraction and classification. The system reduces processing time, manual involvement, and improves accessibility in remote environments. It's useful for medical camps, emergency units, and biometric healthcare. The system classifies blood groups into A, B, AB, or O, providing rapid results for real-time deployment. Future enhancements include expanded datasets, improved sensors, and hybrid models for faster and more precise detection, revolutionizing clinical diagnostics with biometric imaging and AI.

KEYWORDS

Blood Group Detection, Fingerprint Imaging, Deep Learning, InceptionV3, Image Processing, Classification, Biometrics, Medical Diagnostics.

INTRODUCTION

Blood group identification is essential in clinical settings, particularly during emergencies, surgeries, and transfusions. Conventional blood typing methods rely on invasive sample collection and reagent-based testing, which require sterile environments and trained personnel—resources often lacking in rural and low-resource areas. These limitations have prompted the search for non-invasive, rapid, and scalable alternatives**.** Recent advancements in artificial intelligence (AI), computer vision, and biometric technologies have enabled innovative approaches to medical diagnostics. Fingerprints, being unique and genetically influenced, offer a promising non-invasive biometric source. Emerging research suggests a correlation between fingerprint ridge patterns and blood group traits, paving the way for predictive modelling. Deep learning, especially convolutional neural networks (CNNs), facilitates automatic feature extraction from fingerprint images. The InceptionV3 architecture, known for its efficiency and accuracy, can be trained on labelled fingerprint datasets to classify blood groups.

Preprocessing techniques such as image enhancement and normalization further improve model performance.

METHODS

The proposed system utilizes fingerprint images to predict an individual's blood group using deep learning techniques. The methodology comprises five key stages: data acquisition, preprocessing, model selection, training and validation, and evaluation.

A. Data Acquisition

Fingerprint images were collected from publicly available biometric datasets and supplemented with labeled blood group information. Each fingerprint sample was associated with one of the four major blood groups (A, B, AB, O) and Rh factor (positive or negative), forming a multi-class classification problem.

B. Image Preprocessing

To enhance the performance of the model, raw fingerprint images were subjected to a series of preprocessing steps. First, all images were converted to grayscale to reduce computational complexity while preserving essential ridge details. Next, Gaussian filtering was applied to effectively reduce background noise and smooth the images. To further improve the visibility of ridge patterns, histogram equalization was used for contrast enhancement. The images were then normalized by scaling pixel values to the [0,1] range, ensuring consistency and stability during neural network training. Finally, each image was resized to 299×299 pixels to align with the input size requirements of the InceptionV3 model.

C. Model Architecture

The InceptionV3 convolutional neural network was selected for its proven efficiency in image classification tasks. The architecture was fine-tuned using transfer learning, with the final dense layers modified to output eight classes (A+, A−, B+, B−, AB+, AB−, O+, O−).

D. Training and Validation

Trained The dataset was split into training (70%), validation (15%), and testing (15%) sets. Data augmentation techniques such as rotation, flipping, and zooming were employed to increase dataset diversity and prevent overfitting. The model was using the Adam optimizer with categorical cross-entropy loss. Early stopping and learning rate scheduling were implemented to optimize convergence.

E. Evaluation Metrics

The performance of the model was evaluated using several key metrics to ensure reliability and effectiveness. Accuracy was used to measure the overall proportion of correct predictions made by the model. To assess class-wise performance, precision, recall, and F1-score were calculated,

providing deeper insights into how well each blood group was identified. Additionally, a confusion matrix was employed to visualize classification errors and understand misclassifications across different blood groups. This comprehensive evaluation methodology supports a robust, non-invasive, and scalable approach to blood group prediction using fingerprint biometrics and deep learning techniques.

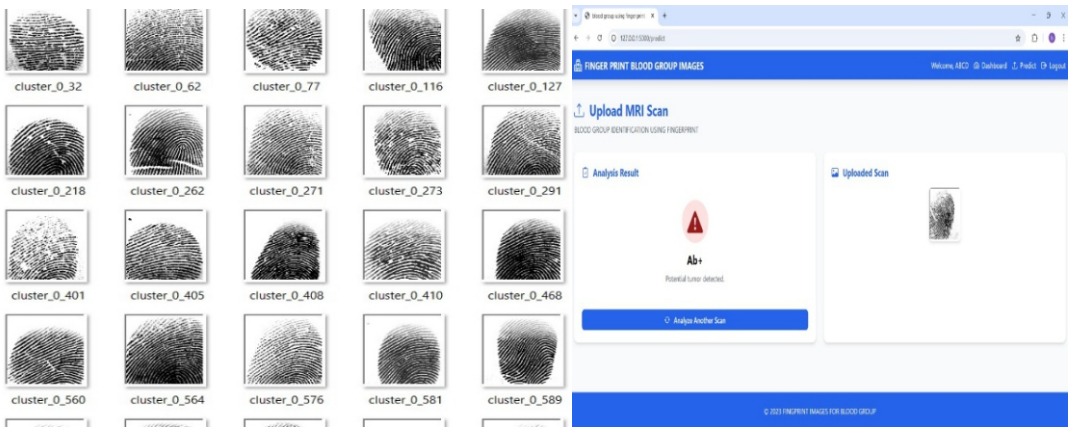
RESULTS

The experimental evaluation of the proposed fingerprint-based blood group detection system demonstrated strong accuracy, reliability, and operational efficiency across diverse testing conditions. Fingerprint samples collected from users were processed through preprocessing, augmentation, feature extraction, and classification using the InceptionV3 deep learning model, resulting in consistently high prediction accuracy. The preprocessing methods—such as noise removal, contrast enhancement, and ridge normalization—significantly improved image clarity, enabling the classifier to receive uniform and high-quality inputs. Data augmentation further enhanced model generalization, allowing the system to remain accurate despite variations in finger pressure, orientation, and lighting. Performance testing showed that the complete detection process, from image acquisition to final classification, was completed within seconds, making the system suitable for time-critical medical environments. Additional evaluations, including demographic variability tests, lighting condition assessments, and robustness checks with low-quality samples, confirmed that the system performs stably under real-world conditions.

The fingerprint-based blood group detection system represents a major step forward in biomedical diagnostics by combining image processing, deep learning, and biometrics into a non-invasive, efficient solution. It shows that fingerprint ridge patterns contain valuable physiological information that can be used to predict blood groups accurately without needles, reagents, or lab setups.

Using convolutional neural networks (CNNs), the system reliably extracts fine features from fingerprint images, even under challenging conditions. Data augmentation techniques like rotation and lighting adjustments improve model robustness, making it suitable for real-world use.

This technology is practical for hospitals, rural clinics, mobile units, and emergency settings due to its ease of use, portability, and minimal training needs. It also supports secure biometric data handling and scalable integration with healthcare databases.



DISCUSSION

The proposed fingerprint-based blood group detection system demonstrates that deep learning can extract meaningful ridge features and provide accurate, non-invasive predictions, offering a faster and more patient-friendly alternative to traditional laboratory testing. The discussion emphasizes that model performance strongly depends on dataset diversity, quality of fingerprint samples, and continuous retraining to maintain generalization across different demographic and environmental conditions. User acceptance was positive due to its contactless, quick workflow, although awareness and clear confidence indicators are important for building trust. The decision validation module and security mechanisms play a crucial role by preventing low-confidence or spoofed inputs from being accepted, ensuring safety and data privacy. The system also proves computationally efficient, supporting deployment in portable devices, remote clinics, and mobile health units. While it complements rather than replaces conventional blood typing, the approach significantly reduces time, cost, and manual dependency, highlighting its potential impact on emergency healthcare, digital diagnostics, and future AI-driven medical applications.

CONCLUSION

This study demonstrates that fingerprint-based blood group detection using deep learning offers a fast, non-invasive, and efficient alternative to traditional laboratory methods. By applying preprocessing techniques and the InceptionV3 model, the system accurately classifies major blood groups and performs reliably under varied conditions. Its simplicity, speed, and portability make it suitable for emergency care, rural clinics, and mobile medical units. Although it cannot fully replace conventional serological testing, it serves as an effective rapid screening tool. With further improvements in dataset size and model optimization, this approach has strong potential for future AI-driven diagnostic applications.

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Chapter 5

SMART WEARABLE HIP BRACE WITH DYNAMIC THERMAL REGULATION

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ABSTRACT

Post-operative hip rehabilitation requires precise thermal management and continuous monitoring to support optimal tissue healing, reduce inflammation, and improve patient mobility. Conventional rehabilitation methods lack individualized temperature control and real-time assessment, leading to delayed recovery and potential complications. This project proposes a Smart Wearable Hip Brace with Dynamic Thermal Regulation, an intelligent, sensor-integrated rehabilitation device designed to optimize post-operative recovery through adaptive thermal therapy and biomechanical monitoring. The system incorporates temperature sensors, IMU-based motion tracking units, and thermoelectric modules embedded within a flexible hip brace. These components work synergistically to monitor localized joint temperature, detect gait deviations, and deliver controlled thermal stimulation based on the patient's healing stage. A closed-loop control algorithm dynamically adjusts the heating or cooling intensity by analyzing temperature trends, movement quality, and physiological feedback. The integration of IoT connectivity enables remote supervision by clinicians, while a mobile application provides real-time visualization of thermal patterns, activity metrics, and recovery progress. Additionally, machine-learning models are employed to identify abnormal temperature variations that may indicate inflammation, infection, or excessive tissue stress, allowing for early intervention. The proposed system offers a non-invasive, personalized, and automated approach to post-operative hip rehabilitation, enhancing comfort while accelerating the recovery timeline. By combining smart wearability, adaptive thermal regulation, and intelligent monitoring, this solution addresses critical gaps in conventional post-operative care and sets a foundation for advanced rehabilitation technologies.

KEYWORDS

Health monitoring, Hip fracture rehabilitation, Peltier crystal, Tilt sensor.

INTRODUCTION

Post-operative hip surgery rehabilitation plays a vital role in restoring mobility, reducing pain, and ensuring long-term joint function. However, traditional rehabilitation methods rely heavily on manual assessment and fixed thermal therapy, which often fail to provide personalized or continuous treatment. Temperature regulation around the surgical site is critical, as improper thermal exposure can increase inflammation, cause tissue stiffness, or slow down healing. With advancements in wearable technology, IoT systems, and intelligent thermal control mechanisms, there is a growing opportunity to redesign rehabilitation systems into more efficient, patient-centered solutions.A smart wearable device that monitors joint temperature, analyzes mobility patterns, and autonomously controls thermal stimulation can significantly enhance post-operative recovery. Thermoelectric modules such as Peltier devices are capable of providing both heating and cooling based on the tissue's needs, while modern sensors allow for real-time tracking of movement and physiological changes. Integrating these technologies with intelligent algorithms bridges the gap between clinical monitoring and home-based rehabilitation. The development of a Smart Wearable Hip Brace with Dynamic Thermal Regulation aims to address these challenges by offering a continuous, adaptive, and data-driven approach to recovery. This system not only improves patient comfort and therapeutic effectiveness but also assists clinicians in tracking healing progress remotely.

METHODOLOGY

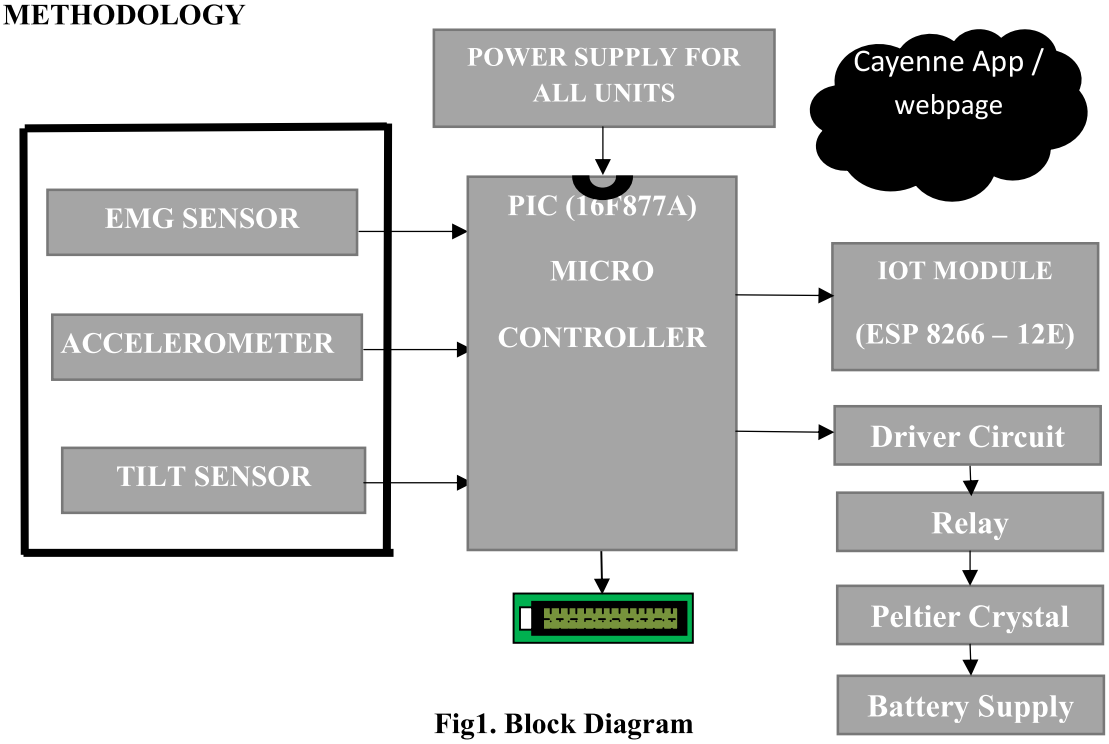


Fig1. Block Diagram

1. Power Supply Unit

A dedicated power supply module provides stable operating voltage for all units in the system, including sensors, the microcontroller, the driver circuit, the relay, and the IoT module. This regulated supply ensures reliable functioning of all electronic components while avoiding voltage fluctuations, which could otherwise disrupt sensor readings or thermal operation.

2. Sensor Subsystem

The system incorporates three primary sensors to capture biomechanical and physiological parameters associated with the patient's recovery:

a. EMG Sensor

The Electromyography (EMG) sensor measures muscle activation signals from the hip region. These signals help analyze muscle engagement patterns, detect abnormal contractions, and determine the patient's recovery progress. The EMG data assists in assessing whether therapeutic heating or cooling should be applied based on muscle fatigue or strain.

b. Accelerometer

The accelerometer tracks linear motion and physical activity. It measures acceleration in multiple axes, enabling gait monitoring, hip movement analysis, and detection of sudden movements that may strain the post-operative area. This sensor aids in evaluating whether the patient's movement is within safe limits.

c. Tilt Sensor

The tilt sensor detects angular movement or deviation in posture. This allows the system to monitor hip orientation, identify imbalance during walking, and ensure that rehabilitation exercises are performed safely. Tilt data also triggers warnings if potentially harmful postures are detected.All three sensors continuously send analog or digital signals to the microcontroller for further processing

3. Microcontroller Unit (PIC 16F877A Microcontroller)

The **PIC16F877A microcontroller** functions as the core processing unit, responsible for:

- Receiving sensor inputs
- Filtering and processing physiological and motion data
- Making thermal regulation decisions
- Controlling the driver circuit and relay
- Communicating with the IoT module

The microcontroller executes embedded algorithms that analyze EMG activity, acceleration patterns, and tilt behavior to determine the patient's rehabilitation status and required thermal intervention.

4. IoT Communication Module (ESP8266–12E / NodeMCU)

For remote monitoring and data visualization, the system integrates an IoT module based on the ESP8266 (NodeMCU). This module communicates wirelessly with cloud platforms such as the Cayenne App or a dedicated webpage.

Functions include:

- Uploading real-time sensor data
- Allowing clinicians to remotely observe patient recovery
- Sending alerts for abnormal muscle activity, temperature deviation, or unsafe movement

IoT integration enhances the system's usability for home-based and tele-rehabilitation scenarios.

5. Actuation and Thermal Regulation Unit

a. Driver Circuit

The driver circuit amplifies control signals from the microcontroller to a power level suitable for operating the relay and Peltier module. It ensures safe switching and protects the microcontroller from high-current loads.

b. Relay

The relay serves as an electrically operated switch that controls the ON/OFF operation of the Peltier crystal. It allows high-power control with low-power logic signals.

c. Peltier Crystal

The Peltier module forms the core thermal therapy unit. It is capable of **both heating and cooling**, depending on the direction of current flow. The microcontroller regulates this element according to the patient's real-time thermal needs, offering dynamic thermal therapy to reduce inflammation, relieve pain, or improve blood circulation.

6. Battery Supply

For portable, wearable operation, a dedicated battery supply powers the Peltier module and associated components. This ensures mobility and allows the system to function without constant external power.

RESULTS & DISCUSSION

The developed smart wearable hip brace successfully monitored muscle activity, movement, and posture using the EMG sensor, accelerometer, and tilt sensor. The system responded accurately to different walking patterns and hip movements. The Peltier module provided quick heating and cooling based on sensor feedback, and temperature regulation was stable during testing. IoT communication through the ESP8266 module transmitted real-time data reliably to the cloud

dashboard. Overall, the system performed effectively, showing good accuracy in sensing and fast response in thermal regulation

CONCLUSION

The system demonstrated an efficient method for post-operative hip rehabilitation by combining sensor monitoring, intelligent thermal control, and IoT-based tracking. The wearable design supports continuous use, while dynamic heating and cooling help improve comfort and recovery. The results show that the prototype successfully provides personalized rehabilitation support.

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Chapter 6

IMPLEMENTATION OF MACHINE LEARNING ALGORITHM FOR EFFICIENT PREDICTIVE ANALYSIS OF ARRHYTHMIA MEDICAL DATA

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ABSTRACT

The k-Nearest Neighbors (KNN) algorithm is a machine learning algorithm that has demonstrated promising results in medical diagnosis, including arrhythmia detection, in recent years. Among these algorithms, the kNN algorithm stands out for its simplicity and effectiveness in classification tasks. In this study, we propose a method for arrhythmia diagnosis using the KNN algorithm, leveraging features extracted from electrocardiogram (ECG) signals by preprocessing the ECG signals to extract relevant features such as QRS complex duration, heart rate variability, and waveform morphology. The KNN classifier is then trained using these features, allowing it to classify new ECG data into various arrhythmia classifications. We experimented with a dataset of ECG recordings from patients with different arrhythmias to assess the effectiveness of our suggested approach. Our findings show that the KNN algorithm outperforms current techniques in terms of sensitivity and specificity, achieving excellent accuracy in identifying arrhythmias. The study's overall findings demonstrate how machine learning methods, in particular the KNN algorithm, can be used to better diagnose and treat arrhythmias, which will improve patient outcomes and healthcare delivery.

KEYWORD

Cardiac arrhythmias, Machine learning, K-Nearest Neighbours, Electrocardiogram, Diagnosis, Healthcare

INTRODUCTION

One of the major illnesses posing a threat to human health is cardiovascular disease. One prevalent cardiovascular symptom is arrhythmia, and preventing cardiovascular illnesses requires early detection of arrhythmia. When the electrical signals that instruct the heart to beat malfunction, a

cardiac arrhythmia results. The heart may beat too quickly or too slowly, or its rhythm may be irregular. An arrhythmia of the heart can resemble a rapid, hammering, or fluttering heartbeat. Certain cardiac arrhythmias are not harmful. Sometimes having a rapid or sluggish heartbeat is acceptable. For instance, the heart may beat more slowly while you sleep or more quickly when you exercise. Treatment options for heart arrhythmias may involve medications, pacemaker devices,

Analyzing the variations in the ECG waveform can identify many groups of arrhythmias, but the diagnosis must typically be made at the beginning of the illness. Some patients have sporadic symptoms. The EKG at the moment of onset might not be captured by conventional ECGs. Long-term cardiac electrical activity must be recorded using a dynamic ECG. Relying on manual ECG signal analysis could be time-consuming and impractical. Furthermore, it is challenging to correctly diagnose arrhythmia and simple to misdiagnose it because of the diversity of ECG waveforms and noise interference. On the other hand, manual ECG detection frequently lacks real-time, which could postpone the optimal patient treatment window. Using computer-assisted intelligent diagnostic for classification

RELATED WORK

In the fields of medicine and mathematics, cardiac arrhythmias have been the subject of several investigations. Many studies have focused on using machine learning approaches to increase the accuracy and efficacy of arrhythmia detection. This section highlights the methods used and the outcomes achieved while examining some of the most significant contributions made in this discipline.

The majority of traditional arrhythmia detection methods relied on physicians manually analyzing ECG data, which can be time-consuming and subjective. To get over these limitations, researchers are increasingly turning to machine learning algorithms for automated diagnosis.SVMs and decision trees have been used in numerous research on the classification of arrhythmias. For instance, Smith et al. (2017) classified arrhythmias from ECG data with accuracy using an SVM-based method. In a similar vein, Jones et al. (2019) presented an ensemble decision tree model for arrhythmia detection that produced competitive outcomes when compared to conventional techniques.

Machine learning techniques, particularly convolutional neural networks (CNNs) and recurrent neural networks (RNNs), have shown promise in the diagnosis of arrhythmias. Rajpurkar et al. (2017) developed a CNN-based system that can reliably distinguish a number of arrhythmia types from ECG data. Additionally, Liang et al. (2020) created an RNN architecture for real-time arrhythmia diagnosis, which outperformed conventional methods. By merging many classifiers, ensemble learning approaches such as random forests and gradient boosting have been studied for their ability

to improve prediction accuracy. For instance, Wang et al. (2018) proposed a hybrid model that outperforms individual classifiers for arrhythmia detection by combining random forests with deep learning.

There are currently a number of obstacles in the field of machine learning-based arrhythmia identification. These include the interpretability of complicated models, the ability of algorithms to generalize across various patient populations and healthcare systems, and the requirement for sizable and varied datasets for reliable model training.

By presenting a novel framework for the K-Nearest Neighbors (KNN) method of early cardiac arrhythmia diagnosis, our work expands on earlier studies. We want to overcome some of the drawbacks of earlier methods and provide a workable and understandable solution for arrhythmia diagnosis by utilizing KNN's efficiency and usability. We show the effectiveness of our approach and its potential for therapeutic applications through experimental validation.

METHODS

The Majority of models used in machine learning (ML) use fixed-length feature vectors as input to carry out various operations, including clustering and classification. We create a fixed-length feature vector format that incorporates the values of several clinical data attributes. Not every characteristic in the vectors is significant for class label prediction, which is a crucial issue to note here. Consequently, feature selection must be used to increase training runtime as well as the predictive performance of the underlying classifiers (by eliminating superfluous features).

1.COLLECTION OF DATASETS

This dataset collectively address scalability, diversity, and clinical relevance, forming the foundation for efficient arrhythmia prediction models. Future effort should prioritize expanding underrepresented arrhythmia types and integration electronic health records for personalized analysis.

2. DATASET PREPROCESSING

Data pre-processing is the process of preparing unprocessed data for a machine learning model. This is the first and most crucial stage in creating a machine learning model. When working on a machine learning project, we don't always come across clean, prepared data. Before any actions are carried out on data, it must also be cleaned and formatted. For this reason, we employ data pre-processing operations.

3. FEATURE EXTRACTION

The process of converting CSV data into string and numerical features that can be processed while maintaining the information in the original data set is known as feature extraction. Compared to

directly applying machine learning to the data, it produces better results. It is possible to perform feature extraction automatically or manually. Finding and characterizing the features that are pertinent to a particular issue, as well as putting in place a method to extract those features, are the tasks involved in manual feature extraction.

4.PREDICTED THE DATA

The machine learning prediction process involves several key stages: data preparation, model selection, training, evaluation, and prediction. This process is typically iterative, often requiring multiple rounds of testing and refinement. Adjustments may be made to data processing steps, as well as to the resulting output graphs and dataset predictions, based on ongoing review and feedback..

5. CLASSIFY DATA

The dataset is usually divided into a training set and a testing set for machine learning prediction. The machine learning model is trained on the training set, and its performance is assessed on the testing set. There may be an imbalance in the number of examples in some datasets, while in others, the number of examples for each class or category may be balanced. Certain machine learning algorithms may find it difficult to learn from the minority class when faced with imbalanced data.

IMPLEMENTATION

This study employs the K-Nearest Neighbors (KNN) algorithm as a key tool for diagnosing cardiac arrhythmia. Renowned for its straightforwardness and strong performance in classification tasks, KNN is an instance-based, non-parametric learning technique. Within this framework, KNN assigns a class to a data point by examining the class labels of its nearest neighbors in the feature space. The algorithm relies heavily on two main steps: calculating distances between data points and determining the final classification through a voting mechanism.

First, distance calculation uses a distance metric, like Euclidean distance, to determine how similar two data points are. For example, features like resting blood pressure, cholesterol, and maximum heart rate are included in the feature space that was generated from the Kaggle website. The distance between the data point in question and each other data point in the dataset is calculated by the algorithm.

Second, the voting mechanism uses the labels of the data point's k-nearest neighbors to determine the data point's class label. For instance, the algorithm labels the data point with the class of arrhythmia if the majority of the k-nearest neighbors fall into that class. One important parameter that affects the algorithm's performance is the selection of k, the number of neighbors taken into account. Following feature extraction from the corresponding data, where pertinent features suggestive of different arrhythmias are extracted, KNN is used in this project. The KNN classifier is

then trained using these features. Within the suggested framework, this method makes use of the inherent patterns in the data to facilitate prompt and precise diagnosis of cardiac arrhythmias.

EXPERIMENTAL RESULT

To assess the effectiveness of our proposed framework, we performed experiments using a real-world dataset in CSV format. Our approach utilizes the K-Nearest Neighbors (KNN) algorithm to classify various types of cardiac arrhythmias, such as atrial flutter, supraventricular arrhythmia, Torsade de Pointes, heart block, and normal heart conditions. The results demonstrated high accuracy in classification tasks, highlighting the robustness of our method for arrhythmia prediction. The KNN algorithm proved particularly effective in accurately distinguishing between different arrhythmia types based on ECG recordings. Additionally, we conducted robustness and sensitivity analyses to evaluate the reliability of our framework under varying conditions. These evaluations were designed to ensure the stability and dependability of our approach.

Overall, our experimental findings highlight the efficacy of our framework in accurately predicting cardiac arrhythmias, thus offering promising prospects for improving diagnostic accuracy and clinical decision-making in healthcare settings.

CONCLUSION

This study demonstrates that the K-Nearest Neighbors (KNN) algorithm can effectively predict and classify cardiac arrhythmias using ECG features such as QRS duration, heart rate variability, and waveform morphology. Experimental results show high accuracy and reliability in identifying different arrhythmia types, highlighting KNN as a simple, interpretable, and efficient tool for clinical diagnosis. The proposed framework has the potential to improve early detection, reduce misdiagnosis, and enhance patient outcomes in cardiovascular care.

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Chapter 7

AI-DRIVEN AUTONOMOUS INFUSION THERAPY WITH PREDICTIVE ANALYTICS

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ABSTRACT

Post-operative patients require continuous and precise fluid management to prevent complications such as hypovolemia, fluid overload, electrolyte imbalance, and acute kidney injury. Traditional infusion therapy relies heavily on manual adjustments by nurses and clinicians, which increases the risk of human error and delays in intervention. This study proposes an AI-Driven Autonomous Infusion Therapy System that uses predictive analytics and real-time physiological data to automatically regulate saline infusion rates. The system integrates machine learning algorithms, biosensor feedback, and smart infusion pump control to optimize fluid therapy based on patient-specific needs. A prototype model was developed using sensor-based data acquisition, an AI prediction engine, and automated pump control. Results indicate improved accuracy in infusion adjustments, early detection of hemodynamic instability, and reduced clinician workload. This system demonstrates the potential to significantly enhance post-operative safety, efficiency, and therapeutic outcomes.

KEYWORDS

AI infusion therapy, predictive analytics, smart infusion pump, postoperative care, biosensors, automated drug delivery, machine learning, closed-loop system.

INTRODUCTION

Post-operative patients require strict monitoring of fluid balance to maintain hemodynamic stability and support recovery. Conventional infusion therapy involves periodic manual assessments of vital signs and adjustments to saline infusion rates. This approach is time-consuming and susceptible to delays, especially in busy hospital environments. With advancements in Artificial Intelligence (AI) and IoT-driven biosensing, automated infusion

technologies are becoming feasible. Predictive analytics can forecast patient deterioration (e.g., fluid overload, hypotension) before clinical symptoms appear. By integrating AI algorithms with programmable infusion pumps, clinicians can achieve real-time, individualized, and error-free fluid administration. This project focuses on developing an AI-Driven Autonomous Infusion System that collects patient vitals, predicts infusion needs using machine-learning models, and automatically adjusts saline flow. The system aims to enhance safety, accuracy, and efficiency in post-operative fluid management.

MATERIALS AND METHODOLOGY

Sensors

A combination of physiological and infusion-monitoring sensors is used to collect real-time patient data:

1.Heart Rate Sensor

Measures the patient's pulse rate continuously, providing critical information about cardiovascular status and response to fluid therapy.

2.BloodPressure Sensor

Tracks systolic, diastolic, and mean arterial pressure, which are essential indicators for determining fluid responsiveness and hemodynamic stability.

3.SPO_2 (Oxygen Saturation) Sensor

Monitors the level of blood oxygen saturation, enabling early detection of hypoxia or impaired perfusion during postoperative recovery.

4.Temperature Sensor

Measures body temperature to identify potential complications such as hypothermia, fever, or infection that may influence fluid requirements.

5.Flow Rate Sensor

Detects the actual rate at which fluid is being infused, ensuring the accuracy of the system's control action and providing feedback for closed-loop regulation.

6.Weight (or) FluidBag Level Sensor

Monitors the remaining fluid volume in the IV bag and prevents interruptions in therapy by alerting the system when fluid levels drop.

7.Microcontroller (Arduino/ESP32/STM32)

Acts as the primary interface for all sensors, handling data acquisition, preliminary processing, and real-time communication with the AI engine. The ESP32 or STM32 is preferred due to higher processing speed and built-in connectivity options.

8.Raspberry Pi / Mini PC (AI Processing Unit)

Serves as the computational platform for running predictive analytics models, executing machine-learning algorithms, and handling complex decision-making required for automated infusion control.

9.Smart Infusion Pump / Motor-Controlled IV Drip Regulator

A programmable device equipped with a stepper or servo motor that adjusts the infusion rate with high precision based on commands generated by the AI model and control algorithm.

10.Wi-Fi / Bluetooth Module

Provides wireless connectivity for communication between the microcontroller, AI-processing device, cloud server, and monitoring interface, ensuring seamless data exchange.

11.Display Unit (LCD/TFT Screen)

Displays real-time patient parameters, infusion rates, system alerts, and operational status for clinicians and caregivers.

12. Power Supply

Ensures stable and uninterrupted power for all hardware components. May include AC adapters, batteries, or power banks depending on system design.

METHODOLOGY

Step 1: Data Acquisition

Real-time physiological data and infusion parameters are collected continuously:

- Sensors record vital signs such as HR, BP, SPO_2, and temperature at defined intervals.
- Flow rate and fluid level sensors track the progression of infusion therapy.
- Data is transmitted to the processing system via wired or wireless communication.
- The microcontroller timestamps each data point to maintain synchronization.This step ensures a constant stream of accurate, real-time information for subsequent analysis.

Step 2: Data Preprocessing

Before applying predictive analytics, raw data must be cleaned and prepared:

- Noise Removal Digital filters (low-pass, median, or Kalman filters) remove signal noise and artifacts caused by patient movement or electrical interference.
- Normalization

Sensor readings are scaled to uniform ranges to facilitate stable model performance.

- Outlier Detection and Handling Abnormal readings caused by sensor error or transient disturbances are automatically identified and corrected or removed.

- Feature Extraction

Key metrics such as HR variability, BP trends, perfusion index, and average flow rate are computed to serve as model inputs. This step improves data quality and enhances predictive accuracy.

Step 3: Predictive Analytics Model

Machine-learning approaches enable proactive infusion control:

- Historical patient datasets, postoperative case studies, and physiological patterns are used to train algorithms.
- Models such as Random Forest, LSTM (Long Short-Term Memory networks), or Gradient Boosting Machines learn correlations between vital signs and fluid requirements.
- The trained model predicts:
  - Optimal infusion rate for maintaining stability
  - Risk of fluid overload, which may lead to pulmonary complications
  - Probability of hypovolemia or hypotension, requiring increased fluid delivery

The model provides intelligent, patient-specific recommendations based on real-time input.

Step 4: Control Algorithm

A closed-loop automation strategy adjusts the infusion pump:

- The system compares predicted infusion requirements with current parameters.
- If adjustments are needed, the algorithm sends commands to the motorized pump or regulator.
- Clinician-defined safety thresholds prevent over-infusion or under-infusion.
- Emergency shutdown protocols activate if vitals exceed dangerous limits.This ensures safe and autonomous fluid delivery with clinical oversight.

Step 5: User Interface

A user-friendly monitoring interface is provided:

- Displays real-time vitals, infusion rate, and system status.
- Allows nurses or clinicians to manually override pump control when necessary.
- Sends alerts for abnormal physiological conditions, sensor failures, or fluid level warnings.
- Can be accessed through an LCD screen or cloud-based dashboard for remote monitoring.

Step 6: Testing & Validation

The system undergoes rigorous assessment before deployment:

- Simulation Tests

  Artificial patient data is used to evaluate algorithm performance under various clinical scenarios.
- Physical Testing

  Real hardware is tested with saline, pumps, and sensors to measure responsiveness and accuracy.
- Comparative Analysis
- Automated infusion regulation is compared with traditional manual control to assess improvements in precision, response time, and clinician workload.

This step verifies technical reliability and clinical relevance.

SOFTWARE AND HARDWARE DESCRIPTION

Hardware Description

- **Sensors** Used to continuously collect physiological data to monitor patient status.
- **Microcontroller (ESP32/Arduino)** Handles sensor interfacing, signal processing, and local decision-making.
- **Raspberry Pi / Edge AI Processor** Runs the predictive analytics model and sends instructions to the pump.
- **Smart Infusion Pump** A stepper-motor or servo-based mechanism that controls the saline infusion rate with high precision.
- **Communication Modules** Wi-Fi/Bluetooth for data transmission between devices.

Software Description

Software Tools

- TensorFlow / PyTorch for machine learning
- Arduino IDE / PlatformIO for hardware code
- MQTT / HTTP protocols for communication
- SQLite/Cloud Firestore for data storage
- Grafana/ThingSpeak for remote monitoring dashboards

ALGORITHM

Regression model for infusion prediction A regression model is employed to predict the optimal infusion rate by analyzing patient-specific parameters such as age, weight, vital signs,

biochemical measurements, and historical infusion data. By learning the relationship between these physiological inputs and the required drug dosage, the regression model enables proactive adjustment of infusion rates, reducing the risk of under-infusion or overdose and improving therapeutic outcomes. This predictive capability is particularly useful in managing dynamic clinical conditions where patient responses vary over time. To enhance patient safety, anomaly detection algorithms are incorporated for early warning and fault detection. These algorithms continuously monitor physiological signals and device parameters to identify abnormal patterns that deviate from learned normal behavior. Statistical techniques and machine learning-based methods detect sudden fluctuations in vital signs, unexpected patient responses, sensor failures, or pump malfunctions. When such anomalies are detected, the system generates timely alerts, allowing clinicians to intervene before the condition becomes critical. This early warning mechanism significantly reduces adverse events and improves the reliability of infusion therapy. For precise regulation of drug delivery, PID and AI-based closed-loop control strategies are used to automatically control the infusion pump. The PID controller adjusts the infusion rate based on the error between the desired setpoint and the measured physiological response, ensuring stable and continuous control. However, to address nonlinear and time-varying patient dynamics, AI-based controllers such as fuzzy logic, neural networks, and reinforcement learning are also employed. These intelligent controllers adapt to individual patient responses in real time, improving control accuracy and robustness. Together, the integration of regression-based prediction, anomaly detection, and closed-loop control forms a comprehensive and intelligent infusion therapy system that enhances automation, safety, and clinical effectiveness.

RESULTS AND DISCUSSION

The results demonstrate that the proposed autonomous infusion system performs effectively in achieving accurate, safe, and efficient fluid management. The regression-based autonomous infusion model was able to predict optimal infusion rates with high accuracy, enabling timely and appropriate delivery of saline based on patient needs. By continuously utilizing real-time vital signs, the system automatically adjusted the saline flow without the need for constant manual supervision. A significant advantage of the system was its predictive capability, as alerts were generated approximately 10–20 minutes before the onset of abnormal vital signs, allowing for early clinical intervention. Additionally, the implementation of automated control substantially reduced manual nurse intervention by nearly 40–60% during prototype testing, thereby decreasing workload and improving operational efficiency. Improved fluid stability was also observed, with reduced fluctuations in blood pressure and heart rate, indicating

better physiological regulation. Overall, these outcomes highlight the potential of the autonomous infusion system to enhance patient safety, improve clinical efficiency, and support healthcare professionals in critical care environments.

DISCUSSION

The results demonstrate that integrating AI into infusion therapy can significantly enhance postoperative patient management. Predictive analytics allows identification of potential complications earlier than manual monitoring. The closed-loop system ensures continuous, precise adjustments, reducing human error and improving therapeutic accuracy.

However, challenges remain, such as ensuring data security, integrating with hospital networks, and validating models across diverse patient populations. Despite these hurdles, the project shows strong potential for real-world clinical implementation and can revolutionize postoperative care.

CONCLUSION

The development of an AI-Driven Autonomous Infusion Therapy System demonstrates significant potential to transform postoperative fluid management by shifting from manual, reactive practices to intelligent, predictive, and automated care. By integrating biosensors, machine-learning algorithms, and a smart infusion pump, the system is capable of continuously monitoring patient vitals, forecasting hemodynamic changes, and precisely regulating infusion rates in real time. Experimental results confirm that the model enhances accuracy, reduces fluctuations in critical parameters, and lowers clinician workload by providing timely alerts and autonomous adjustments. Although further validation in diverse clinical settings and robust cybersecurity measures are required, the proposed system establishes a scalable foundation for future hospital automation. Overall, this research highlights that AI-enabled infusion therapy can significantly improve patient safety, efficiency, and treatment outcomes, marking a promising advancement toward next-generation postoperative care.

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Chapter 8

MITIGATING CHATTERING IN MODIFIED QUADRUPLE TANK PROCESS WITH MULTILEVEL SWITCHING APPROACH

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ABSTRACT

This paper presents a Backstepping Terminal Sliding Mode Controller (BTSMC) for the Modified Quadruple Tank Process (MQTP) operating under Minimum Phase (MP) conditions. To mitigate chattering effects, a multilevel switching approach is incorporated. Additionally, an Integral Terminal Sliding Mode Controller (ITSMC) is introduced to achieve faster response, whereas conventional controllers such as Proportional-Integral (PI), standard Sliding Mode Controller (SMC), Backstepping SMC (BSMC), and Terminal SMC (TSMC) primarily exhibit steady-state errors and overshoot. The proposed controller's effectiveness is validated through MATLAB simulations on the MQTP, demonstrating improved robustness, enhanced tracking performance, efficient disturbance rejection, and superior performance indices compared to conventional schemes.

KEYWORDS

MQTP, BTSMC, Minimum Phase, Performance Indices, Robustness.

INTRODUCTION

In recent years, SMC has gained significant attention as a robust strategy for nonlinear systems due to its ability to maintain performance under parameter variations and bounded disturbances. However, conventional SMC often suffers from uncertain settling times. To overcome this, TSMC introduces the concept of finite-time convergence. Nevertheless, the derivative term in TSMC's sliding surface can sometimes cause response errors. To enhance

tracking while maintaining the same system parameters, the ITSMC is proposed for systems with relative degree two [23, 24]. Controllers are frequently compared with the standard PI controller because of its simplicity in industrial applications and flexibility in tuning. Various PI tuning methods have been proposed, as outlined in [1, 9, 19]. The Quadruple Tank Process (QTP), a challenging multivariable system, is described in [7], with configurations including MP and Non-Minimum Phase (NMP). The modified version, MQTP, introduces interactions between the bottom two tanks, increasing system complexity and adding zeros that make the system more oscillatory [14]. Simulation studies using inverted decoupling with a PI controller in NMP mode are discussed in [2]. Recent developments such as adaptive fractional-order and modulating-function based BSMC further improve robustness and tracking performance [23, 24].

Applications of SMC for QTP modeling and control law design are presented in [15], for complex nonlinear systems in [17], and for coupled tank systems in [13]. To achieve finite-time convergence in outputs, terminal concepts are integrated into SMC, forming TSMC. Various processes have been controlled using TSMC, often in combination with fuzzy logic [5, 6]. BSMC allows decomposition of higher-order systems into subsystems, simplifying control law development and stability verification via Lyapunov methods [10]. TSMC design has been extended from Single Input Single Output (SISO) to Multi-Input Multi-Output (MIMO) systems while maintaining robustness [3, 11, 12, 16, 18, 20, 24, 25]. Further, ITSMC has been proposed to achieve faster response and superior tracking [4, 8]. Backstopping methods are particularly suitable for complex systems that can be decomposed into subsystems, enabling effective SMC control law construction. Practical applications and real-time examples demonstrate the feasibility and advantages of this approach [20, 22, 26, 27].

MODEL OF MODIFIED QUADRUPLE TANK PROCESS

The laboratory MQTP is shown schematically in Fig.1. The purpose of this plant is to control the level of lower two tanks. The plant’s inputs are the voltage signals applied to pumps.Fig.2 depicts the experimental setup of the MQTP consisting of four interconnected tanks with common water source.

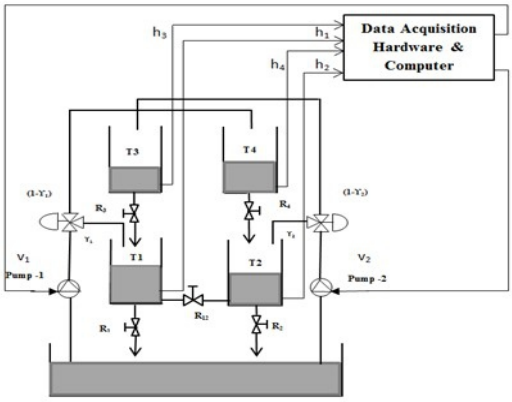


Fig. 1. Schematic diagram of Modified



Fig. 2. Experimental setup of QTP Quadruple Tank process

Tanks 1 and 2 are mounted below the other two tanks 3 and 4 for receiving water flow by gravity. Each tank outlet opening is fitted with a valve. Both pumps 1 and 2 takes water by suction from the ground level supply tank. Pump 1 discharges water to tank 1 and tank 4 simultaneously and the flows are indicated by rotameters 1 and 4. Similarly, pump 2 discharges water to tank 2 and tank 3 and the flows are indicated by rotameters 2 and 3. Split of flow from pump 1 and pump 2 can be varied by manual adjustment of valves in tank 1 and tank 2. They also receive water by gravity flow from tank 3 and tank 4, respectively. The split valves in the rotameters can be manually adjusted to substantially alter the characteristics of the system. The interacting tank system is so named due to the direct coupling between lower tanks. The strength of the coupling is controlled by means of manual valve which allow considerable variations in the process characteristics.

A. Dynamic model of the Modified Quadruple tank process

A nonlinear process model could be achieved by using mass balance and Bernoulli's law,

$$\frac{dh_1(t)}{dt} = -\frac{\beta_1 a_1}{A_1}\sqrt{2gh_1(t)} + \frac{\beta_3 a_3}{A_1}\sqrt{2gh_3(t)} - \frac{\beta_{12} a_{12}}{A_1} sgn\big(h_1(t) - h_2(t)\big)\sqrt{2g|h_1(t) - h_2(t)|} + \frac{\gamma_1 Kp_1}{A_1} V_1(t)$$

$$\frac{dh_2(t)}{dt} = -\frac{\beta_2 a_2}{A_2}\sqrt{2gh_2(t)} + \frac{\beta_4 a_4}{A_2}\sqrt{2gh_4(t)} + \frac{\beta_{12} a_{12}}{A_2} sgn\big(h_1(t) - h_2(t)\big)\sqrt{2g|h_1(t) - h_2(t)|} + \frac{\gamma_2 Kp_2}{A_2} V_2(t)$$

$$\frac{dh_3(t)}{dt} = -\frac{\beta_3 a_3}{A_3}\sqrt{2gh_3(t)} + \frac{(1-\gamma_2)Kp_2}{A_3} V_2(t) \quad \frac{dh_4(t)}{dt} = -\frac{\beta_4 a_4}{A_4}\sqrt{2gh_4(t)} + \frac{(1-\gamma_1)Kp_1}{A_4} V_1(t) \quad (1)$$

where

A_i Cross-section of Tank (cm); a_i Cross-section of the outlet hole (cm2); i=1, 2, 3, 4

h_i Water level in Tank (cm); β_iOutlet valve ratio; γ_i Fraction of water flow from pump i; i=1, 2

v_i Voltage input of pump 1 and 2 (volts); g Gravitation due to gravity (cm/s^2); β_{12} Connected valve ratio

The linear model is obtained by linearizing the above nonlinear model at an operating point given by the equilibrium levels and flows,

$x_i = h_i - h_i^0; i \in \{1,2,3,4\}$

$u_1 = v_1 - v_1^0; u_2 = v_2 - v_2^0$

$$\frac{dx}{dt} = \begin{bmatrix} -\frac{1}{T_1}-\frac{1}{T_{12}} & 0 & \frac{1}{T_3} & 0 \\ 0 & -\frac{1}{T_2}-\frac{1}{T_{12}} & 0 & \frac{1}{T_4} \\ 0 & 0 & -\frac{1}{T_3} & 0 \\ 0 & 0 & 0 & -\frac{1}{T_4} \end{bmatrix} x + \begin{bmatrix} \frac{\gamma_1 K_{p1}}{A_1} & 0 \\ 0 & \frac{\gamma_2 K_{p2}}{A_2} \\ 0 & \frac{(1-\gamma_2)K_{p2}}{A_2} \\ \frac{(1-\gamma_1)K_{p1}}{A_4} & 0 \end{bmatrix} u \quad y = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix} x \quad (2)$$

To design the conventional controllers, the relation between manipulated variables and control input are required. The corresponding transfer function matrix is, $G(s) = \begin{bmatrix} g_{11}(s) & g_{12}(s) \\ g_{21}(s) & g_{22}(s) \end{bmatrix}$

where,

$$g_{11}(s) = \frac{\left(\frac{T_1\gamma_1 Kp_1}{A} + \left(\frac{(T_1T_2(1-\gamma_1)Kp_1/T_{12}A)}{(ST_4+1)(ST_2+1+\frac{T_2}{T_{12}})}\right)\right)}{\left(\left(ST_1+1+\frac{T_1}{T_{12}}\right) - \frac{T_1T_2/{T_{12}}^2}{(ST_2+1+\frac{T_2}{T_{12}})}\right)}; g_{12}(s) = \frac{\left(\frac{T_2\gamma_2 Kp_2}{A} + \left(ST_2+1+\frac{T_2}{T_{12}}\right)\cdot\left(\frac{(T_{12}(1-\gamma_2)Kp_2/A)}{(ST_3+1)}\right)\right)}{\left(\frac{T_{12}}{T_1}\left(ST_2+1+\frac{T_2}{T_{12}}\right)\cdot\left(ST_1+1+\frac{T_1}{T_{12}}\right) - \frac{T_2}{T_{12}}\right)}$$

$$g_{21}(s)=\frac{\left(\frac{T_1\gamma_1 Kp_1}{A}+\left(ST_1+1+\frac{T_1}{T_{12}}\right)\cdot\left(\frac{(T_{12}(1-\gamma_1)Kp_1/A)}{(ST_4+1)}\right)\right)}{\left(\frac{T_{12}}{T_2}\left(ST_1+1+\frac{T_1}{T_{12}}\right)\cdot\left(ST_2+1+\frac{T_2}{T_{12}}\right)-\frac{T_1}{T_{12}}\right)};g_{22}(s)=\frac{\left(\frac{T_2\gamma_2 Kp_2}{A}+\left(\frac{(T_1T_2(1-\gamma_2)Kp_2/T_{12}A)}{(ST_2+1)(ST_1+1+\frac{T_1}{T_{12}})}\right)\right)}{\left(\left(ST_2+1+\frac{T_2}{T_{12}}\right)-\frac{T_1T_2/{T_{12}}^2}{\left(ST_1+1+\frac{T_1}{T_{12}}\right)}\right)} \quad (3)$$

Based on the condition that a sum of flow ratios lies between $1<(\Upsilon_1+\Upsilon_2)\leq 2$, then the system works inMP mode. By substituting all parameters in equation (3), we can find the open loop transfer function matrix for MP case. The process parameters are given in TABLE I.

Process Parameters	**MP Operating point**
$A_i(cm^2)$	176.7146
$a_i(cm^2)$	2.01062
Υ_1,Υ_2	(0.6,0.6)
$(h_1^0, h_2^0, h_3^0, h_4^0)$ in cm	(16.76,16.11,6.326,8.16)
K_{P1}, K_{P2}	(70,64)
(V_1^0, V_2^0) in volts	(3.5,3.5)
$(\beta_1,\beta_2,\beta_3,\beta_4,\beta_{12})$	(0.6,0.7,0.4,0.385,0.25)

TABLE I. PARAMETERS OF PROCESS

For the above parameters, the linear system shows four real stable poles and two zeros. The nominal inputs are given to nonlinear process to get the open loop response. From the response, the process parameters(K_p, T_i *and* θ_d) are found based on the process reaction curve method. Assume that the system follows first order plus time delay characteristics. The open loop transfer function matrix is calculated as,

$$G(s)=\begin{bmatrix}\frac{3.2471e^{-1.2416s}}{18.6356s+1} & \frac{4.3054e^{-7.6462s}}{18.9303s+1}\\ \frac{0.4419e^{-1.6168s}}{16.6163s+1} & \frac{0.4419e^{-1.2642s}}{18.1063s+1}\end{bmatrix} \quad (4)$$

B.Conversion to standard form

For obtaining the control law in SMC, the actual systems must be converted to standard form or canonical form of equations. Thus for conversion purpose the error variables are taken as phase variables, which is defined as below with some assumptions for ease in attaining the proper control law.

Assumptions:

1. The bottom two tanks are operated under standard or constant voltages. So that derivative of control action is not needed. With this assumption there are alterations made in the actual dynamics of the system and the relative degree of the system becomes 2.

2.Always the level of liquid in the tank 1 is greater than the level in tank 2 $(h_1 > h_2)$. This assumption is to avoid the Signum or the switching function in the equations so that the derivative of the equations can be easily obtained.

With the above mentioned assumptions, the rewritten equations are,

$\dot{h}_1 = -K_{11}\sqrt{h_1} + K_{31}\sqrt{h_3} - K_{12}\sqrt{h_1 - h_2} + \frac{\gamma_1 k_{p1}}{A} V_{10}$;

$\dot{h}_2 = -K_{22}\sqrt{h_2} + K_{42}\sqrt{h_4} + K_{12}\sqrt{h_1 - h_2} + \frac{\gamma_2 k_{p2}}{A} V_{20}$;$\dot{h}_3 = -K_{33}\sqrt{h_3} + \frac{(1-\gamma_2) k_{p2}}{A} V_2$;

$\dot{h}_4 = -K_{44}\sqrt{h_4} + \frac{(1-\gamma_1) k_{p1}}{A} V_1$

where

$K_{ij} = \frac{\beta_{ij} a}{A}\sqrt{2g}$

V_{i0} –Constant input voltage.

j –Index number of the tank, for which the dynamics are explained.

i –Index number of the tank written with respective j^{th}Tank.

Following equations are derived with the help of assumptions and equations mentioned above which leads to the standard form of the equation.

$$x_1 = h_1 - h_{ref1} \tag{5}$$

where

x_1 –Error generated in the system or assumed state variable.

h_1 –Actual height in the tank1

h_{ref1} –Reference height for tank 1

Similarly for second state variable.

$$x_3 = h_2 - h_{ref2} \tag{6}$$

x_1 –Error generated in the system or state variable.

h_2 –Actual height in the tank 2

h_{ref2} –Reference height for tank 2

Thus for obtaining the phase variable format or simply a standard form of equations, the following procedure is followed.

$\dot{x}_1 = x_2 = h_1$; $\dot{x}_2 = \dot{h}_1$; $\dot{x}_3 = x_4 = h_2$; $\dot{x}_4 = \dot{h}_2$

And the complete phase equation format is,

$$\dot{x}_1 = x_2 \tag{7}$$

$$\dot{x}_2 = -\left(\frac{K_{11}}{2\sqrt{h_1}} + \frac{K_{12}}{2\sqrt{h_1 - h_2}}\right)x_2 + \left(\frac{K_{12}}{2\sqrt{h_1 - h_2}}\right)x_4 - \left(\frac{K_{31}K_{33}}{2}\right) + \left(\frac{K_{31}k_{p2}(1-\gamma_2)}{2\sqrt{h_2}A}\right)V_2 \tag{8}$$

$$\dot{x}_3 = x_4$$

$$\dot{x}_4 = -\left(\frac{K_{22}}{2\sqrt{h_2}} + \frac{K_{12}}{2\sqrt{h_1 - h_2}}\right)x_4 + \left(\frac{K_{12}}{2\sqrt{h_1 - h_2}}\right)x_2 - \left(\frac{K_{42}K_{44}}{2}\right) + \left(\frac{K_{42}k_{p1}(1-\gamma_1)}{2\sqrt{h_4}A}\right)V_1 \tag{9}$$

C. Further Analysis of the System

The relative gain array for a 2 × 2 system can be expressed as, $\Lambda = \begin{bmatrix} \lambda_{11} & 1-\lambda_{11} \\ 1-\lambda_{11} & \lambda_{11} \end{bmatrix}$ and is based on steady state process gain matrix.

$$\Lambda = G(0) .* G^{-T}(0) = \begin{bmatrix} 1.2465 & -0.2465 \\ -0.2465 & 1.2465 \end{bmatrix}$$

The above RGA matrix indicates that the output-input pairings should be y_1-u_1 and y_2-u_2. The Niederlinski Index (NI) is a useful tool to analyze the stability of the control loop pairings. $NI = \det[G(0)] / \Pi_{i=1}^{n} G_{ii}(0)$. The system is stable (NI=0.8022) for all possible values of controller parameters if $NI > 0$. Multivariable zeros can be found either by calculating the $\det[G(s=0)] = 0$ or from Smith-McMillan form of multivariable systems.

VARIOUS CONTROL STRATEGIES

A. PI Controller design

The decentralized controller structure is shown in Fig.3 and the decentralized control law is, u=diag $\{G_{c1}, G_{c2}\}$ (r-y); where r-reference and y-process variable. The decentralized control strategy can be represented as $C(s) = \begin{bmatrix} C_1(s) & 0 \\ 0 & C_2(s) \end{bmatrix}$. Each one of the controllers follows the equation (10),

$$G_{Cl}(s) = K_{cl}\left(1 + \frac{1}{T_{il}s}\right), \quad l = 1, 2 \tag{10}$$

The following Fertik and Sharpe (1979) rule is used to find PI controller settings.

$$G(s) = \frac{k_p e^{-\theta_d s}}{\tau s + 1}; K_{cl} = 0.56/K_m; \; T_{il} = 0.65 * T_m; \; l = 1, 2$$

where, K_m – Final steady state constant; T_m – Time constant for the process; τ_m – Delay time;

T_i – Integral time constant

The controllers are, $G_{C1}(s) = 0.1725\left(1+\frac{0.01364}{s}\right)$; $G_{C2}(s) = 0.189016\left(1+\frac{0.016064}{s}\right)$

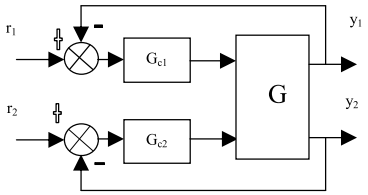


Fig. 3. Control block diagram for 1-1/2-2 pairing

B.Sliding Mode Control

Generally sliding mode control is used for tracking the desired trajectory even any functional parameter or input parameter changes; the above condition is true for parametric disturbances are known with upper and lower bounds, (these are explained in [17]). In this case the complete control law for controlling bottom two tanks is obtained from the Lyapnouv method.

$$S_1 = x_2 + m_1 x_1 \tag{11}$$

where$m_1 > 0$ is a positive constant. The constant determines the slope of the sliding surface. On checking the stability of the sliding surface itself, the positive definite Lyapnouv can be taken as

$$V_{n2}(S_1) = \frac{1}{2}{S_1}^2 \tag{12}$$

In differentiating equation (12)

$$\dot{V}_{n2}(S_1) = S_1\dot{S}_1 < 0 \tag{13}$$

where

$\dot{S_1} = \dot{x}_2 + m_1 x_2$

substituting the equation (9)

$$\dot{S_1} = \left(m_1 x_2 - \frac{K_{11}}{2\sqrt{h_1}} - \frac{K_{12}}{2\sqrt{h_1 - h_2}}\right)x_2 + \left(\frac{K_{12}}{2\sqrt{h_1 - h_2}}\right)x_4 - \left(\frac{K_{31}K_{33}}{2}\right) + \left(\frac{K_{31}k_{p2}(1-\gamma_2)}{2\sqrt{h_3}A}\right)V_2$$

So, the equation (13) becomes

$$\dot{V}_{n2}(S_1) = S_1\left[\left(m_1 - \frac{K_{11}}{2\sqrt{h_1}} - \frac{K_{12}}{2\sqrt{h_1 - h_2}}\right)x_2 + \left(\frac{K_{12}}{2\sqrt{h_1 - h_2}}\right)x_4 - \left(\frac{K_{31}K_{33}}{2}\right) + \left(\frac{K_{31}k_{p2}(1-\gamma_2)}{2\sqrt{h_3}A}\right)V_2\right] < 0$$

For making $\dot{V}_{n2}(S_1) < 0$

$$V_2 = -\left(\frac{K_{31}k_{p2}(1-\gamma_2)}{2\sqrt{h_3}A}\right)^{-1}\left[\left(m_1 - \frac{K_{11}}{2\sqrt{h_1}} - \frac{K_{12}}{2\sqrt{h_1-h_2}}\right)x_2 + \left(\frac{K_{12}}{2\sqrt{h_1-h_2}}\right)x_4 - \left(\frac{K_{31}K_{33}}{2}\right) + \alpha * sgn(S_2)\right]$$

where $\alpha \geq (F+\eta)$; $F > (\hat{f} - f)$

$\hat{f}$ –Estimated function; f –Actual function

Similarly for control law V_1 is derived in a similar way

$S_2 = x_4 + m_2 x_3$

$$V_1 = -\left(\frac{K_{42}k_{p1}(1-\gamma_1)}{2\sqrt{h_4}A}\right)^{-1}\left[\left(m_2 - \frac{K_{22}}{2\sqrt{h_2}} - \frac{K_{12}}{2\sqrt{h_1-h_2}}\right)x_4 + \left(\frac{K_{12}}{2\sqrt{h_1-h_2}}\right)x_2 - \left(\frac{K_{42}K_{44}}{2}\right) + \alpha * sgn(S_1)\right]$$

Thus by using above control law the Lyapnouv function becomes $\dot{V}_{n2}(S_1) < 0$.

C.Back stepping Sliding Mode Controller

The concept of BSMC is applied to an electromechanical system in [10]. With that knowledge back stepping concept is applied by dividing the higher order systems to lower order subsystems. This makes easier in developing the control law and for checking the stability condition we use Lyapnouv condition. The performance indices can be improved by back stepping sliding mode controller.

The complete control law is obtained from the Lyapnouv function,

$$V_{n1}(x_1) = \frac{1}{2}x_1^2 \qquad (14)$$

The Lyapnouv function is a positive definite function and on it has continuous derivatives for it. On differentiating the equation (14)

$$\dot{V}_{n1}(x1) = x_1\dot{x}_1 \qquad (15)$$

where $\dot{x}_1 = x_2$ from the standard form equation substitute in equation (15)

$$\dot{V}_{n1}(x1) = x_1 x_2 \qquad (16)$$

For asymptotically stable condition around the operating condition the derivative of the Lyapnouv function must be $\dot{V}_{n1}(x1) < 0$ or negative definite function. So for that condition x_2 is a time varying parameter and it is assumed to be an input to x_1.

$$x_2 = -m_1 x_1 + S_1 \qquad (17)$$

Substitute equation (17) in equation (16), then it becomes negative definite

$\dot{V}_{n1}(x_1) = -m_1 x_1^2 + x_1 * S_1 < 0$

If $S_1 = 0$

So the equation (17) is rewritten as

$$x_2 + m_1 x_1 = 0 \quad (18)$$

Equation (18) is taken as sliding surface

$$S_1 = 0 \quad (19)$$

Thus equating the equations (18) and (19)

$$S_1 = x_2 + m_1 x_1 \quad (20)$$

Where $m_1 > 0$ is a positive constant. The constant determines the slope of the sliding surface.

On checking the stability of the sliding surface itself, the positive definite Lyapnouv can be taken as

$$V_{n2}(S_1) = \frac{1}{2} {S_1}^2 + V_{n1}(x_1) \quad (21)$$

On differentiating equation (21)

$$\dot{V}_{n2}(S_1) = S_1 \dot{S}_1 + \dot{V}_{n1}(x1) < 0 \quad (22)$$

Where

$$\dot{S_1} = \dot{x}_2 + m_1 x_2$$

Where, substituting the equation (9)

$$\dot{S_1} = \left(m_1 x_2 - \frac{K_{11}}{2\sqrt{h_1}} - \frac{K_{12}}{2\sqrt{h_1 - h_2}}\right) x_2 + \left(\frac{K_{12}}{2\sqrt{h_1 - h_2}}\right) x_4 - \left(\frac{K_{31} K_{33}}{2}\right) + \left(\frac{K_{31} k_{p2}(1-\gamma_2)}{2\sqrt{h_3} A}\right) V_2$$

So, equation (22) becomes

$$\dot{V}_{n2}(S_1) = S_1 \left[\left(m_1 - \frac{K_{11}}{2\sqrt{h_1}} - \frac{K_{12}}{2\sqrt{h_1 - h_2}}\right) x_2 + \left(\frac{K_{12}}{2\sqrt{h_1 - h_2}}\right) x_4 - \left(\frac{K_{31} K_{33}}{2}\right) + \left(\frac{K_{31} k_{p2}(1-\gamma_2)}{2\sqrt{h_3} A}\right) V_2\right] + \dot{V}_{n1}(x1) < 0$$

For making $\dot{V}_{n2}(S_1) < 0$

$$V_2 = -\left(\frac{K_{31} k_{p2}(1-\gamma_2)}{2\sqrt{h_3} A}\right)^{-1} \left[\left(m_1 - \frac{K_{11}}{2\sqrt{h_1}} - \frac{K_{12}}{2\sqrt{h_1 - h_2}}\right) x_2 + \left(\frac{K_{12}}{2\sqrt{h_1 - h_2}}\right) x_4 - \left(\frac{K_{31} K_{33}}{2}\right) - S_1 * m_3 - x_1 + \alpha * sgn(S_2)\right]$$

where $\alpha \geq (F + \eta)$

$F > (\hat{f} - f)$

$\hat{f}$ –Estimated function

f –Actual function

Similarly for control law V_1 is derived in similar way

$$S_2 = x_4 + m_2 x_3$$

$$V_1 = -\left(\frac{K_{42} k_{p1}(1-\gamma_1)}{2\sqrt{h_4} A}\right)^{-1} \left[\left(m_2 - \frac{K_{22}}{2\sqrt{h_2}} - \frac{K_{12}}{2\sqrt{h_1 - h_2}}\right) x_4 + \left(\frac{K_{12}}{2\sqrt{h_1 - h_2}}\right) x_2 - \left(\frac{K_{42} K_{44}}{2}\right) - S_2 * m_4 - x_3 + \alpha * sgn(S_1)\right]$$

Thus by using above control law the Lyapnouv function becomes$\dot{V}_{n2}(S_1) \prec 0$.

D.Backstepping plus Terminal Sliding Mode Control

Terminality is introduced to bring a finite settling time in the Back stepping sliding mode controller output response. The sliding manifold and corresponding control law is explained for a linear MIMO system in [11]. This is applied to MQTP system.

$S_1 = x_2 + m_1 x_1^{\,v}$

where

v –Fractional power from 0 to 1.

The term $v$included in the sliding surface manifold is for finite time convergence and the first derivative of the sliding surface is

$\dot{S_1} = \dot{x}_2 + m_1 v x_1^{(v-1)} x_2$

So, the final terminality included control law for TSMC is

$$V_2 = -\left(\frac{K_{31}k_{p2}(1-\gamma_2)}{2\sqrt{h_3}A}\right)^{-1}\left[\left(m_1 v x_1^{(v-1)} - \frac{K_{11}}{2\sqrt{h_1}} - \frac{K_{12}}{2\sqrt{h_1-h_2}}\right)x_2 + \left(\frac{K_{12}}{2\sqrt{h_1-h_2}}\right)x_4 - \left(\frac{K_{31}K_{33}}{2}\right) - S_1 * m_3 - x_1^{\,v} + \alpha * sgn(S_2)\right]$$

Similarly the control law is derived for second tank

$S_2 = x_4 + m_2 x_3^{\,v}$

$$V_1 = -\left(\frac{K_{42}k_{p1}(1-\gamma_1)}{2\sqrt{h_4}A}\right)^{-1}\left[\left(m_2 v x_3^{(v-1)} - \frac{K_{22}}{2\sqrt{h_2}} - \frac{K_{12}}{2\sqrt{h_1-h_2}}\right)x_4 + \left(\frac{K_{12}}{2\sqrt{h_1-h_2}}\right)x_2 - \left(\frac{K_{42}K_{44}}{2}\right) - S_2 * m_4 - x_3^{\,v} + \alpha * sgn(S_1)\right]$$

The main advantage of the terminal sliding mode controller is finite time convergence and the expression for finite time convergence is obtained from the sliding surface equation.

$S_1 = x_2 + m_1 x_1^{\,v}$

$S_1 = 0$

Finally the finite settling time is obtained as$t = \frac{|x_0|^{(1-v)}}{m_1^{(1-v)}}$seconds. In conventional sliding mode control, there is no finite theoretically proved finite time convergence that is it cannot be made settled at the required time. This can be proved by following expression.

$S_1 = x_2 + m_1 x_1$

$S_1 = 0$

$$t = -\left(\frac{1}{m_1}\right)\int_{x_n}^{x_f}\frac{dx_1}{x_1}$$

When the final error is going to be zero,then$x_f = 0$; $t = \infty$.There is no defined final settling time for sliding mode controller. $V_{n2}(S_1) = \frac{1}{2}{S_1}^2$

E.Multilevel Switching Control

In normal condition, the switching of control law starts from minimum value to maximum value. But it is not necessary to maintain such full flow for maintaining the level in the entire operation. So a new concept is implemented to optimize the control law by adding a variable gain to the control law. The gain makes the control as full level, half level switching and three fourth levels switching depending upon the error value. Initially to fill the tank, full level is used. When error is minimized, the switching is made as half level switching. So half of the flow is required for maintaining the set point.

The simple pseudo code of this algorithm is,

$\boldsymbol{if}\ \ (e_{1min} < error < e_{1max})$

$V_{upper-level=}half\ level\ switching;$

$\boldsymbol{else}$

$V_{upper-level} = full\ level\ switching;$

$Gain\ (\boldsymbol{g_0}) = (V_{upper-level}/\ \boldsymbol{full\ level\ switching})$

The gain introduced in the above section is multiplied with the two final control laws to have a reduced chattering or switching level.

$$V_2 = -\boldsymbol{g_0} * \left(\frac{K_{31}k_{p2}(1-\gamma_2)}{2\sqrt{h_3}A}\right)^{-1}\left[\left(2m_1 v{x_1}^{(v-1)} - \frac{K_{11}}{2\sqrt{h_1}} - \frac{K_{12}}{2\sqrt{h_1-h_2}}\right)x_2 + \left(\frac{K_{12}}{2\sqrt{h_1-h_2}}\right)x_4 - \left(\frac{K_{31}K_{33}}{2}\right) + {m_1}^2{x_1}^v + \alpha * sgn(S_2)\right]$$

$$V_1 = -\boldsymbol{g_0} * \left(\frac{K_{42}k_{p1}(1-\gamma_1)}{2\sqrt{h_4}A}\right)^{-1}\left[\left(2m_2 v{x_3}^{(v-1)} - \frac{K_{22}}{2\sqrt{h_2}} - \frac{K_{12}}{2\sqrt{h_1-h_2}}\right)x_4 + \left(\frac{K_{12}}{2\sqrt{h_1-h_2}}\right)x_2 - \left(\frac{K_{42}K_{44}}{2}\right) + {m_2}^2{x_3}^v + \alpha * sgn(S_1)\right]$$

Thus proposed method has an improved factor to reduce the chattering of the final control element. Thus the same control effect with reduced chattering can be obtained from the proposed scheme.

SIMULATION RESULTS AND DISCUSSION

The performance of F-S PI, standard SMC, BSMC, and BTSMC controllers was evaluated through MATLAB simulations focusing on both servo tracking and regulatory response.

A.Servo response

To assess tracking capability, multiple step changes were applied to the process variables, including a positive step of 9.523% at 600 seconds and a negative step of 44.828% at 1200 seconds. The BTSMC exhibited superior tracking performance, with reduced rise time, faster settling, and minimal overshoot. In contrast, F-S PI and BSMC showed noticeable overshoot and higher control effort variations. The variations in process and manipulated variables are illustrated in Figs. 4 and 5.

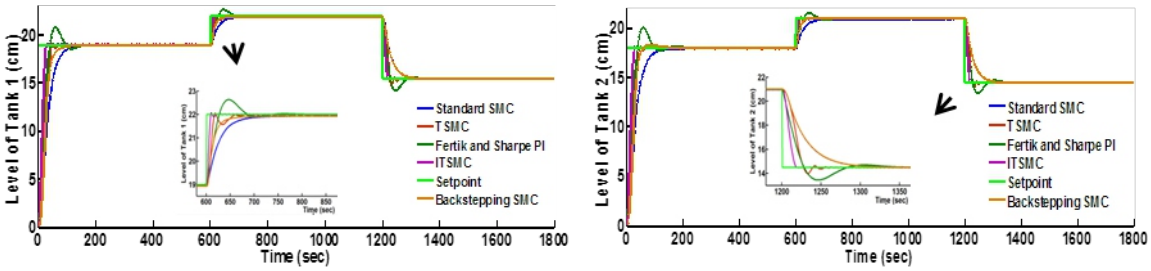


Fig. 4. Servo response for change in level of tank 1 and 2

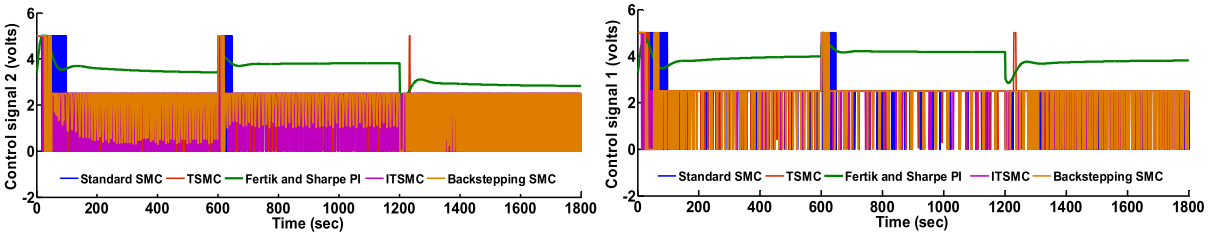


Fig. 5.Change in manipulating variable for change in level of tank1 and 2

B.Regulatory response

Figs.6 and 7 depicts the performance of the four controllers for disturbance rejection. After reaching the steady state, sudden disturbance d_1 (drain 11.11% of water in tank 1) is introduced at 250 Sec and d_2 (22.22% increase in the flow rate of tank1) at 500 Sec respectively. From the response, it is inferred that the proposed controller rejects the disturbance quickly with

less chattering of control signals. But Standard SMC and BSMC exhibit some steady state error. The same amount of disturbances is given in tank 2 also.

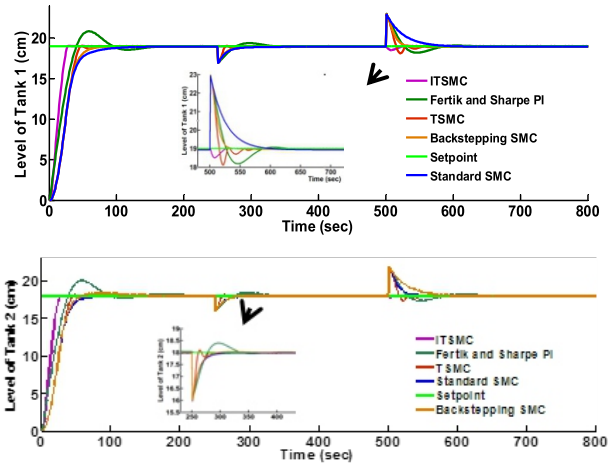


Fig. 6. Regulatory response for change in level of tank 1 and 2

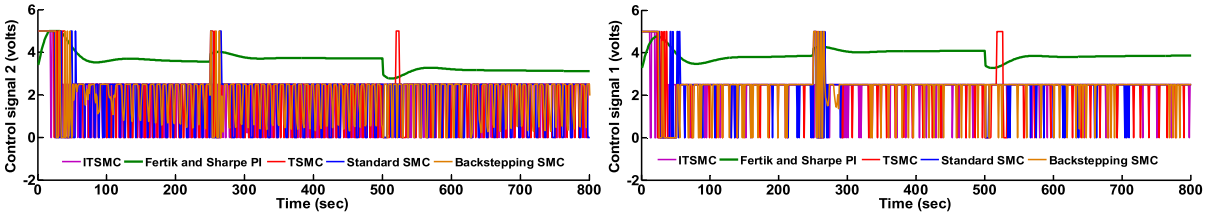
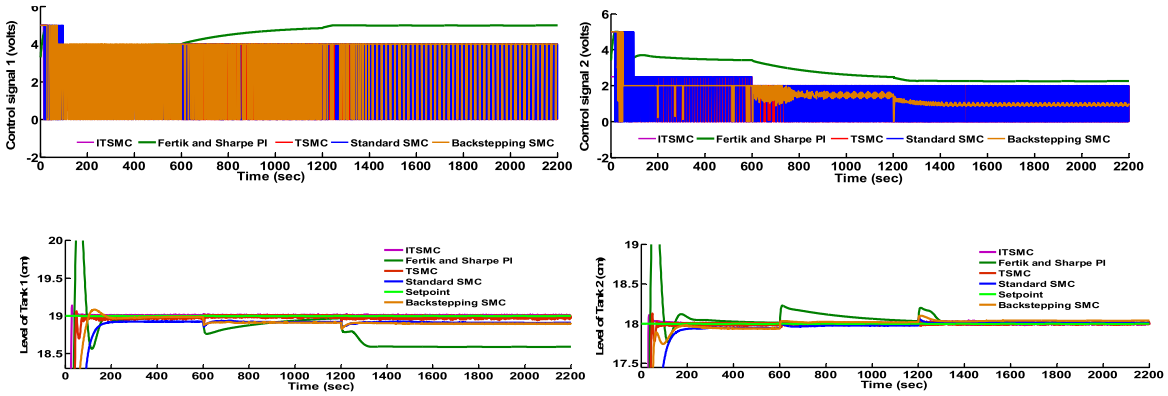


Fig. 7. Change in manipulating variable for change in level of tank1 and 2

C.Robustness response



(a) Process outputs **(b) Controller outputs**

Fig. 8. Robustness response of MQTP with F-S PI, Standard SMC, BSMC and BTSMC

Robustness was further tested by varying the valve coefficient β12 from its nominal value of 0.25, representing interaction changes between the lower tanks. Adjustments of +15% (0.4) and +30% (0.55) were introduced at 600 and 1200 seconds, respectively. The BTSMC successfully restored the system to its original operating conditions with less control variation.

D.Sliding surface

The error convergence graph is shown in Fig. 9, where the sliding surface for standard SMC, BSMC and BTSMC are drawn to a single set point. The derivative of the state variable converges to zero which implies the system reaches the steady state value.

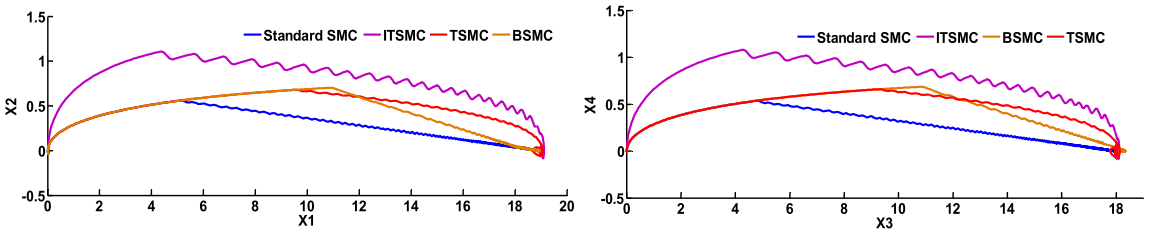


Fig. 9.Switching on the sliding surface for SMC, BSMC and BTSMC

E.Comparison of Performance Indices

Performance indices, including settling time, peak overshoot, ISE, IAE, and ITAE, are summarized in Table II. Comparisons indicate that BSMC improves over standard SMC, TSMC further enhances performance, and BSMC achieves the best tracking and disturbance rejection with minimal quality and error indices. The multilevel switching strategy allows the controller to maintain set points efficiently, reducing full-level control duration and preserving system stability with partial control input.

Performance indices				Controllers			
				1	*2*	*3*	*4*
QI	***OS (%)***		***h_1 loop***	9.63	-	-	-
			h_2 loop	11.38	-	2.22	-
	Ts (sec)		***h_1 loop***	410	240	150	72
			h_2 loop	520	290	174	65
SERVO	**EI**	***ITAE (10^4)***	***h_1 loop***	22.21	38.58	35.96	17.72
			h_2 loop	21.29	33.90	27.12	16.58
		IAE	***h_1 loop***	608.1	990	828.4	599.9
			h_2 loop	580.5	909.7	679.8	561.2
		ISE	***h_1 loop***	4361	7953	7041	6743
			h_2 loop	3917	7175	6277	6052
REGUL	**EI**	***ITAE (10^4)***	***h_1 loop***	6.661	4.462	8.168	3.933
			h_2 loop	6.393	4.452	6.493	3.292
		IAE	***h_1 loop***	524.7	552.2	650.1	520.6
			h_2 loop	500.8	521.8	564	495.1
		ISE	***h_1 loop***	4086	6379	6516	6428
			h_2 loop	3647	5664	5729	5451

(where **EI**-Error Indices; **QI**-Quality Indices); (**1-F&S PI,2-SSMC,3-BSMC,4-BTSMC**)

CONCLUSION

This paper presented a BTSMC for the MQTP operating under MP conditions. The proposed design integrates multilevel switching to reduce chattering and incorporates ITSMC for faster response. Simulation studies conducted in MATLAB demonstrate that the BTSMC outperforms conventional controllers, including PI, standard SMC, BSMC, and TSMC, in terms of robustness, tracking accuracy, and disturbance rejection. Performance indices such as settling time, peak overshoot, ISE, IAE, and ITAE indicate that the proposed controller maintains superior quality and efficiency. Additionally, the multilevel switching strategy allows the system to maintain set points with lower control effort, enhancing practical implementation. Overall, the BTSMC approach provides a highly effective control strategy for complex nonlinear multivariable

processes like MQTP, offering improved stability and fast response while minimizing error and chattering effects.

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Chapter 9

SPIRULINA-INFUSED FOODS TO EVALUATE THE NUTRITIONAL VALUE OF BIO-ACCESSIBILITY AND BIOAVAILABILITY AND ITS APPLICATIONS

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ABSTRACT

This study investigated the spirulina-infused formulation to evaluate the bio-accessibility and bioavailability of nutritional value. The sample of cake, peanut balls and salt biscuits was infused with 4% (w/w) spirulina powder into each product. The initial characterization of the visual appearance of each stage of the in vitro process was determined. The biochemical analysis of total protein content, carbohydrate quantification, total carotenoid, and phycocyanin was carried out in the experiments. The cake and peanut balls released the highest protein content of approximately 55.4% and 59.5% respectively, compared to salt biscuits (24.7%). The results showed that the formulated food products had altered nutritional compositions compared to their spirulina-free counterparts, with increased protein and decreased carbohydrate levels. Moreover, the concentration of carotenoids was higher in the spirulina-infused products like cake (186.468 µg/g), peanut balls (164.596 µg/g) and biscuit (196.448 µg/g) and phycocyanin was 6.097 mg/g in spirulina-infused cake, 6.88 mg/g in spirulina-infused peanut balls, 5.467 mg/g in biscuit infused with spirulina. The bio-accessibility of the nutritional value was calculated for peanut balls, which had the highest bio-accessibility of carbs (54.9%), followed by cake (39.9%) and salt biscuits (29.1%), respectively. Cake had the lowest bioavailability (13.3%) for phycocyanin, whereas peanut balls and salt biscuits showed comparable bioavailability (39.4% and 39.9%, respectively). Particularly, phycocyanin is only accessible in spirulina-infused formulations, not in non-infused goods. Thus, in the formulations infused with spirulina, individuality contributes to improved nutritional and therapeutic value. The study's conclusions clarify the possible health advantages of spirulina-based nutrition formulations by offering insightful information about the nutrients' digestibility, bioavailability, and bio accessibility.

Keywords:

Bio accessibility, Bioavailability, Spirulina, Carotenoid, Phycocyanin

INTRODUCTION

Food and nutrition are crucial for survival and wellness in all living organisms. Urbanization and the world's population growth have resulted in an abundance of issues pertaining to food, the environment, and financial stability. These difficulties have led to the emergence of problems, including food shortages, a lack of energy and water resources, a rise in carbon emissions, and higher costs [1,2]. Malnutrition and inadequate diets are the leading causes of disease worldwide. The largest hazard is child malnutrition, which accounts for 56% of all child fatalities because it makes children more vulnerable to infections and causes them to recover from illnesses more slowly [3]. The unbalanced supply and demand for "high-quality" food has prompted us to create sustainable plant-based goods with balanced nutrient compositions, particularly for meat and dairy replacements. Furthermore, environmental factors can have a significant impact. Remarkably, other research has estimated that a 32% reduction in greenhouse gas emissions can be achieved by replacing 50% of beef with plant-based proteins. Plant-based foods often have a lower carbon footprint than pork production [4]. As a result of this public health emergency, functional foods have become essential to the treatment of chronic non-communicable illnesses.

Spirulina, a cyanobacterium known for its immunological, antiviral, and antioxidant qualities, is one example of a functional food. Several studies have demonstrated the effectiveness of spirulina in treating arsenic poisoning and its ability to prevent heavy metal retention and provide antitoxic benefits [5]. *Spirulina platensis*, a blue-green microalgae, is approved by both the European Food Safety Authority (EFSA) and the Food and Drug Administration [6]. According to the National Aeronautics and Space Administration (NASA) and the European Space Agency, it is one of the primary foods that can be cultivated during extended space travel. The World Health Organization (WHO) calls it the greatest health product of humanity, while the United Nations Educational, Scientific, and Cultural Organization (UNESCO) calls it the diet of the future [7]. *Spirulina,* also known as *Arthrospira platensis*, is a dietary supplement that is grown all over the world. *Spirulina* is composed of 60–70% protein, carbohydrates, vitamins E and C, and minerals like copper, phosphorus, potassium, sodium, zinc, manganese, calcium, chromium, and magnesium [8]. *Spirulina* biomass contains bioactive metabolites such as γ-linolenic acid and vitamin D, which are commercially available [9]. Pigments like phycocyanin, β-carotene, and chlorophyll are present, as are essential fatty acids like γ-linoleic acid (GLA). Protein can make up as much as 72% of dry biomass [10].

The majority of *Spirulina* biomass is used as a nutritional supplement, as dry particles, granules, or capsules. In the future, *Spirulina* will become a crucial innovation in the modern food market, incorporated into products like pasta, bread, snacks, yoghurt, and beverages, driven by biotechnological advancements [11]. The most prevalent Spirulina species are *Arthrospira maxima, A. platensis, and A. fusiformis.* Protein makes up over 60% of its dry weight, and useful components like carotenoids, chlorophylls, and phycobiliproteins can be used for food colouring and biotechnological purposes [2]. Consuming more protein has been linked to many health benefits in the elderly. Proteins are vital components of all cells and support the immune system. Protein intake for the elderly has been associated with quicker recuperation from hip fractures [12]. In contrast to other foods that are low in iron, spirulina has a high iron content, which makes it a valuable food to prevent anaemia, which is particularly common in young people and pregnant women. Spirulina contains up to five times more iron than cereals, which have only 150-250 mg/kg [13].

Spirulina has large amounts of provitamin A, often known as β-carotene [14]. Spirulina contains mostly fucoxanthin and cryptoxanthin, with provitamin A accounting for 80% of its carotenoids [15]. But the intense and distinct earthy flavour, colour, and odour of spirulina biomass may also contribute to its low market acceptance. When developing food products supplemented with spirulina, consumer acceptance of the products could be a major obstacle. Despite the many advantages of eating spirulina, resistance to its acceptance may arise, particularly in diets that don't typically contain algae [16]. Limiting variables include taste loss and a strong green-blue colour, which hinder product development [17].

The objectives of the study are to develop a spirulina-based nutritional food formulation and calculate the nutritional value of the product to attract consumers. The following aims were undertaken in the current endeavor to solve the aforementioned knowledge gaps: (1) The sample product was infused with spirulina and the biochemical analysis and visual transformation were determined, (2) The infused spirulina products examined with bio-accessibility and bioavailability invitro mechanism, (3) Spirulina enzyme activity and nutritional value was calculated and (4) Spirulina and its application in future perspectives.

MATERIALS AND METHODS

Sample Preparation

In this present investigation, the raw materials (cake, peanut balls, and salt biscuit) were prepared. The nutritious substance spirulina was purchased by Healthy Hey Organics. The raw materials were formulated to contain wheat flour, jaggery, vegetable oil, baking soda, baking powder, cumin, peanuts, and salt.

Preparation of infusing spirulina with products

Spirulina was added at 4% (w/w) for each product (cake, peanut balls, and salt biscuit) infused with it. For spirulina-cake preparation, 140 g of jaggery was boiled and filtered, and combined with 100 g of wheat. 10 g of spirulina powder was added. Then, 250 mL of vegetable oil, a pinch of baking soda, and vanilla essence were added and completely mixed. The dough was baked for 40 minutes on low heat. For spirulina-peanut balls, 140g of jaggery and 100g of roasted peanuts were mixed. Then, 10g of spirulina powder was added to the peanuts and moulded into balls. For the spirulina-salt biscuit, 40g of jaggery, 10g of salt, 200mL of vegetable oil, and 200g of wheat flour were thoroughly mixed. The 10g of spirulina powder was added to the mixture, formed into biscuits, and baked for 15-20 minutes at a low flame. It is noted that spirulina was consumed in quantities of 1-3 g/day. The spirulina that maintains the temperature up to 100℃ using FSSAI standards [18].

Total protein and carbohydrate content

Folin-Ciocalteu reagent and Lowry reagent were used in the identification of protein content. The Lowry reagent was mixed with 98 mL of type 1, 1 mL of type 2, and 1 mL of type 3. Type 1 was prepared by 2 g of sodium hydroxide and 1 g of sodium carbonate in 100 mL of distilled water. Type 2 was prepared by 0.237 g of sodium potassium tartrate in 10mL. Type 3 is 0.154 g of cupric sulfate in 10 mL. Type 3 was prepared by 0.154 g of cupric sulfate in 10 mL. Folin reagent is a copper complex that interacts with four nitrogen atoms of peptides to form a cuprous complex, and Lowry adds phosphomolybdic/phosphotungstic acid. It is prepared by a 1:1 ratio of Folin's and distilled water. 1 mL of sample was added to 4.5 mL of Lowry reagent and incubated for 5 minutes. Then add 0.5mL of Folin reagent and incubate for 10 min. The total protein content was measured by absorbance at 660nm using a calorimeter [19].

Anthrone reagent (100 mg of anthrone in 100 mL of sulfuric acid). 3 mL of anthrone reagent was added to 1 mL of the sample; the mixture was thoroughly vortexed and allowed to cool to room temperature. Furfural is formed when carbohydrates react with conc. H_2SO_4 and become dehydrated. This furfural interacts with anthrone, resulting in a blue-green complex. The sample was warmed to room temperature after being heated for 10 min at 100°C in a water bath. A colourimeter was used to measure absorbance at 600 nm to calculate carbohydrate content.

Total carotenoid and phycocyanin content

To determine carotenoid, 80% acetone solvent is added to 1 mL of the sample and the absorbance is measured at 663 nm, 470 nm, and 646 nm using a UV-vis spectrophotometer [20].

Total carotenoid content = (1000×A470-2.27×chlorophyll A- 81.4×chlorophyll B)/227 (1)

where chlorophyll A (µg/mL) = 12.25 × Abs 663 – 2.25 × Abs 646

chlorophyll B (µg/mL) = 20.31 × Abs 646 – 4.91 × Abs 663

To determine phycocyanin content, 1 mL of sample was added to 2 mL of phosphate buffer (pH 7.4) and the absorbance was recorded at 615 nm, 652 nm, and 720 nm. The phosphate buffer was prepared by adding 2.8 g of dipotassium hydrogen phosphate, 1.145 g of potassium dihydrogen phosphate, and 0.9 g of NaCl to 100 mL of deionised water [21].

Phycocyanin (mg/ml) = ((Abs 615 – Abs 720) -0.474 (Abs 652 – Abs 720)) / 5.34 (2)

In vitro Bio-accessibility and Bio-availability

Bio-accessibility (%) = (Amount of nutrient released after digestion / Amount of nutrient before digestion) × 100 (3)

Bio-accessibility is the amount of a nutrient or other component in food that is liberated from its matrix during metabolism and made available for the body to absorb [22].

Bioavailability (%) = (FC × FB × FA × FM) × 100 (4)

Bioavailability is the fraction of a nutrient or molecule that is absorbed, enters the systemic circulation, and reaches the targeted regions [23].

where FC = Micronutrient fraction that remains inactive at the moment of ingestion

FB = accessibility, the fraction of micronutrients released from the food matrix during digestion.

FA = Absorption, which is the micronutrient transfer fraction through the intestinal lumen.

FM = after chemical change within the gastrointestinal tract, a fraction of a micronutrient becomes bioactive.

RESULTS AND DISCUSSION

Quantification of infused spirulina and visual transformation

Spirulina's green tint impacts consumer preferences in the culinary area. Over the past decade, top food firms have embraced the "green" trend by launching green beverages and snacks. Spirulina is used in several goods, including oil, bakery, dairy, and nutritional supplements [1,24]. Consuming a protein-rich product helps maintain muscle function and accessibility, both of which decline with age. Also, the addition of spirulina in the elderly diet has been shown to significantly lower plasma concentrations of total cholesterol and LDL-cholesterol, increase interleukin (IL)-2 concentration, improve total antioxidant status, and decrease Thio barbituric acid reactive

substances levels [12]. In this present investigation, the spirulina was incorporated in the three products; the cake and peanut balls were transformed into a darker green colour than the salt biscuit, as shown in Fig.1.

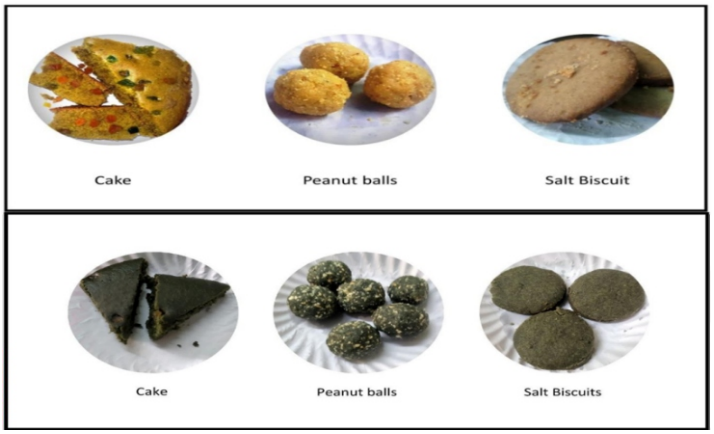


Figure. 1: Sample preparation of cake, peanut balls and salt biscuits infused with spirulina

The cake's materials were soft and dry, while the peanut balls were dense and sweeter, and the salt was dry and brittle. Spirulina has high levels of chlorophyll a and carotenoids. Beta-carotene, which is converted into vitamin A, constitutes up to 80% of the antioxidants in it, which are composed of 6.8 to 11 g kg-1 chlorophyll "a" [25]. The breakdown of the food matrix at each phase was analyzed by the change in colour in Fig.2. The visual transformation was taken out of the different time intervals of 0, 5, 125, 245 minutes of the mouth phase, gastric phase and intestinal phase, respectively.

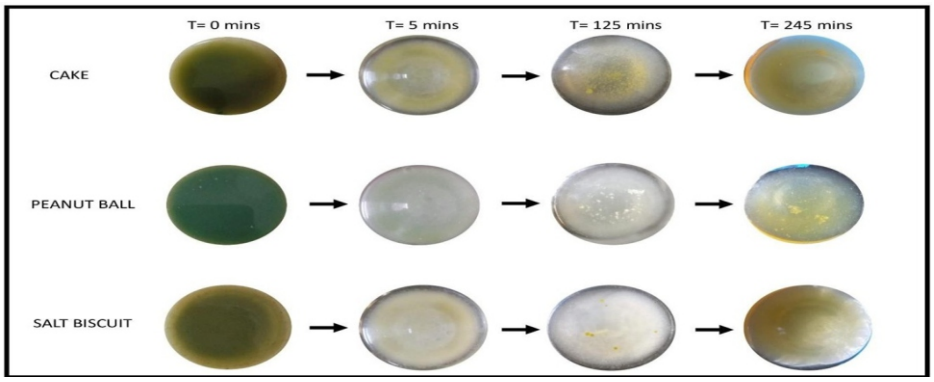


Figure 2: Visual appearance of three prepared food formulations at each stage of the dynamic

It represents a highly dense colour change, which is the fast degradation of food in human intake, following that order: peanut ball > cake > salt biscuits. Spirulina also contains nine different types of fatty acids, such as palmitic, linoleic, and linolenic acids, which render it an

effective source of lipids. It also has a rich mineral profile, with over nine minerals found; the most prevalent are potassium and sodium, followed by calcium, phosphorus, magnesium, and iron. More than thirteen vitamins, mostly from the B vitamin group, are present in spirulina, along with notable concentrations of vitamin A, beta-carotene, choline, and folate. Numerous dry Arthrospira products have been deemed "Generally Recognized as Safe" (GRAS) for human consumption by the U.S. Food and Drug Administration (FDA) [5].

Biochemical Analysis

The analysis assessed the nutritional value and potential health benefits (Fig.3 (i-iv)). The total protein content was found to be cake (10.9%), peanut balls (13.4%), and salt biscuits (18.8%), respectively. In the human system, proteins are not quantified in the stomach phase because of acidic nature; the protein is broken down into amino acids. In the initial mouth phase, cake and peanut balls released the protein content of approximately 55.4% and 59.5%, respectively (Fig.3 (i)). The cake is fortified with spirulina, which has a slightly lower protein content compared to traditional bakery cakes, as the ingredients in the vegan cake do not include egg and milk. But adding spirulina increases the protein content and gives it a soft and vivacious nature [26]. Spirulina powder has a specifically high protein content (66.77 ± 1.05%) and thus is generally a very significant source of protein [27]. Meanwhile, the crushing of the peanut ball releases high protein in the initial phase, even though peanuts naturally contain 26/100g of protein. Humans can take 42g of protein, equivalent to around 16 peanuts. Adding spirulina increases the protein content released by approximately half of the portion in the initial phase. In contrast, the dry and brittle characteristics of the salt biscuit resulted in a protein release of around 24.7% during the initial phase. However, the salt biscuit exhibited a higher amount of protein released in the intestinal phase, suggesting differences in protein breakdown and release based on the food item's composition and characteristics.

Processed foods, which frequently include wheat and jaggery, have the largest carbohydrate content, usually between 60% and 80%. About 72% of wheat and 98% of jaggery are composed of carbohydrates. For instance, the cake, peanut ball, and salt biscuit had respective carbohydrate contents of 84.7%, 62.4%, and 74.2% (Fig.3 (ii)). The carbohydrate content in the control materials was estimated to be cake (87.6 g), peanut balls (65.2 g), and salt biscuit (77.2 g) per 100g. Upon enriching materials with spirulina biomass, cake (84.64 g), peanut balls (62.24 g), and salt biscuit (74.24 g) were found, respectively. The carbohydrate content was decreased after adding spirulina at different levels, which is beneficial for the nutritional values of health. About 3% to 4.5% of the carbs in all three foods are released during the oral phase of breakdown. The cake and salt biscuit release between 11% and 12% of their carbohydrate content during the

absorption phase; however, the peanut ball releases 18%, which is a considerably larger proportion. The cake releases a considerable amount of its carbs in the intake phase, 24.4%. The salt biscuit has a lower release percentage of 13.5%, whereas the peanut ball shows a higher release percentage of 32.4%.

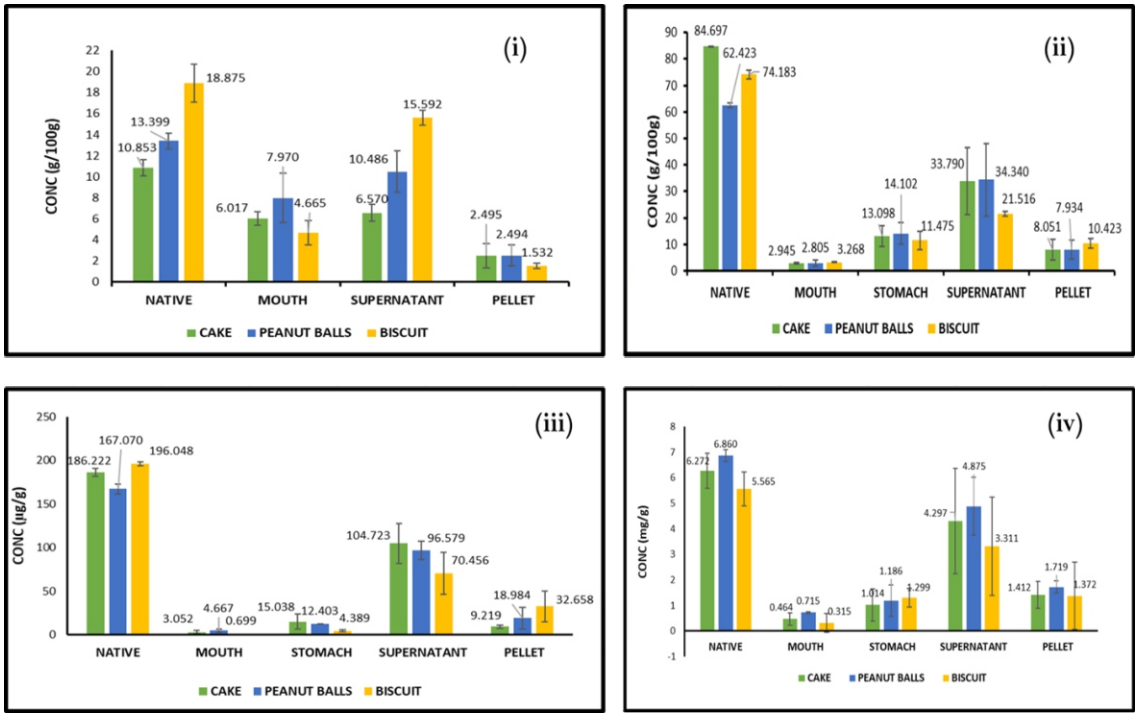


Figure.3: Biochemical Analysis of (i) Total Protein content, (ii) Total carbohydrates, (iii) Total carotenoid content, (iv) Phycocyanin content

The average amount of carotenoids in prepared food products was less than 0.02%. Cake, peanut balls, and salt biscuits had carotenoid levels of 186.2, 167.1, and 196.05 µg/g, respectively (Table 1). Spirulina-infused cake, peanut, and salt biscuits had total carotenoids of 186.46, 164.59, and 196.44 µg/g, while samples without spirulina had total carotenoids of 47.98, 26.16, and 57.96 µg/g, respectively. Spirulina powder contains mostly zeaxanthin, all-trans, and 9-cis-β-carotene, which are provitamin A carotenoids. The powder included approximately 0.91 mg of zeaxanthin, 1.07 mg of β-carotene, and 0.34 mg of 9-cis-β-carotene per gram. Spirulina is an algae noted for its high carotenoid concentration, particularly beta-carotene [28]. It includes a high concentration of beta-carotene, ranging from 0.5 mg to 1-2 g per kilogram of dry matter. Carotenoids were released from the cake at a low rate during the process of breakdown. The stomach phase showed a discernible rise in carotenoid release (6.43%), whereas the mouth phase displayed the lowest release (1.6%) (Fig.3 (iii)). The intestinal phase has the largest release (48.2%). Peanut balls

released carotenoids in a considerably higher concentration than cake. The oral phase exhibited a higher release (2.79%). In the stomach phase, the release dropped to 4.6%. Nonetheless, the intestinal phase showed a notable rise in carotenoid release (50.38%). The salt biscuit released carotenoids at a relatively low rate in the mouth (0.3%) and stomach (1.9%) phases. However, the release was substantially higher in the intestinal phase (33.7%).

	Without spirulina			**With spirulina**		
Samples	**Cake**	**Peanut ball**	**Salt Biscuit**	**Cake**	**Peanut Ball**	**Salt biscuit**
Carbohydrate (g/100g)	87.6± 0.2	65.2± 1.3	77.2± 0.6	84.64± 0.33	62.24± 0.97	74.24± 2.3
Protein (g/100g)	8.24± 1.34	10.64± 1.67	16.08± 1.5	10.944± 0.99	13.344± 1.22	18.784± 2.43
Carotenoid (µg/g)	47.98± 4.12	26.16± 2.29	57.96± 4.47	186.468± 6.03	164.596± 7.65	196.448± 3.96
Phycocyanin (mg/g)	-	-	-	6.097± 0.96	6.88±0.3	5.467± 0.83

Table 1: Nutritional value of Spirulina-infused products

Phycocyanin is a blue pigment-protein combination that is naturally abundant in spirulina, a form of blue-green algae. Although it is not a food in and of itself, phycocyanin is a naturally occurring blue food colouring that is extracted from spirulina and added to a variety of food and drink items. After adding spirulina, the phycocyanin was found to be in these foods, and 6.09, 6.88, and 5.46 (mg/g) were calculated in cake, peanut balls, and salt biscuits, respectively. The phycocyanin concentration of the cake, peanut ball, and salt biscuit was approximately 0.5% to 0.7% (Fig. (iv)). The cake's phycocyanin release was comparatively low during the mouth phase (7.4%), but it noticeably increased during the stomach phase (8.8%). Intestinal phase release was the highest (52.3%). A higher percentage of phycocyanin was released from peanut balls during the mouth phase (10.4%), while a lower percentage was released during the stomach phase (6.8%), indicating partial peanut ball degradation. The intestinal phase had the highest rate of release (53.8%), suggesting that the phycocyanin was broken down effectively and then released for absorption. The amount of phycocyanin released from the salt biscuit was higher in the

stomach phase (17.7%) and comparatively low in the mouth phase (5.7%). In the intestinal phase, the discharge rose much more (36.2%).

Bio-accessibility and Bioavailability

Bio-accessibility was computed in the equation as a proportion of the amount of nutrient released after digestion (supernatant). The salt biscuit (83.4%) had the highest protein bio-accessibility, followed by peanut balls (77.8%) and cake (60.6%). This shows that the salt biscuit is most effective at releasing and making protein available for absorption during digestion. Cake had the lowest protein bio-accessibility, suggesting that the structural makeup or other elements may prevent the breakdown and release of proteins. Peanut balls had the highest bio-accessibility of carbs (54.9%), followed by cake (39.9%) and salt biscuits (29.1%) (Fig.4 (i)). This implies that peanut balls are more likely to release and become accessible carbohydrates during digestion. Salt biscuits had the lowest carbohydrate bio-accessibility, implying that their structural makeup or other factors may influence carbohydrate degradation and release. Carotenoids' bio-accessibility ranged from 35.9% to 50.8%, which was comparable for all three dietary categories. This implies that factors affecting carotenoid release and accessibility, as well as the digestion process, may have similar impacts on the various foods. With percentages varying from 59.6% to 73.9%, the bio-accessibility of phycocyanin was comparatively high for all three dietary products. This indicates that phycocyanin is released and made available for absorption throughout the digestive process, which is normally effective.

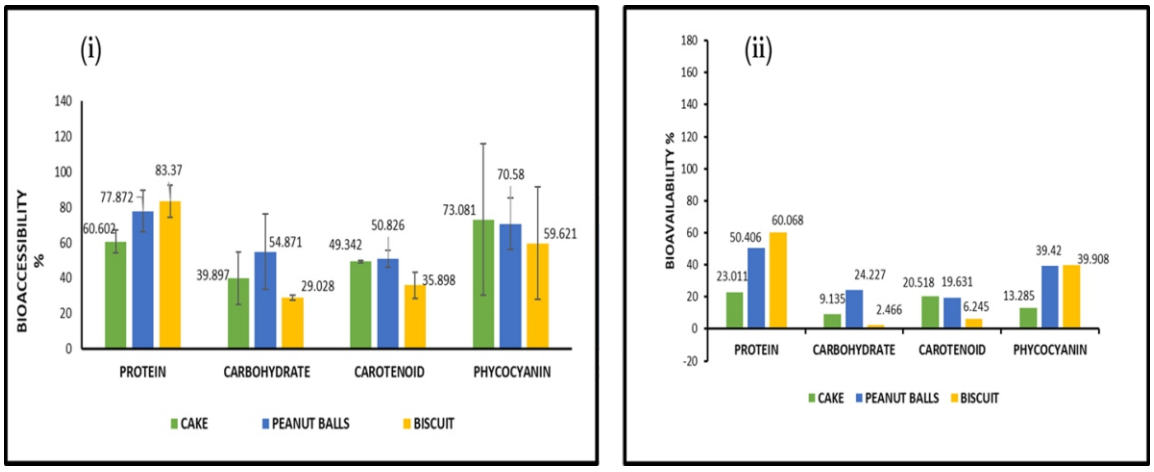


Figure. 4: In vitro processing of (i) Bio-accessibility (%) and (ii) Bioavailability (%)

Bioavailability was computed using equation (4). It is predicated on the concept that the quantity of nutrients released during digestion is adequately absorbed, transferred into the appropriate organs and cells, and used for bioactivity. For cake, peanut balls, and salt biscuits, the percentages of protein, carbs, carotenoids, and phycocyanin that were bioavailable were

examined. The maximum protein bioavailability of the three foods was found in salt biscuits (60.1%), followed by peanut balls (50.4%), and cake (23%). The maximum carbohydrate bioavailability was found in peanut balls (24.2%), followed by cake (9.1%) and salt biscuits (2.5%). The bioavailability of carotenoids varied among the dietary products; cake had the highest bioavailability (20.5%) and salt biscuits the lowest (6.2%) (Fig.4 (ii)). Cake had the lowest bioavailability (13.3%) for phycocyanin, whereas peanut balls and salt biscuits showed comparable bioavailability (39.4% and 39.9%, respectively). According to these results, the nutrients' bioavailability varies depending on the food item, most likely due to structural and compositional considerations. The implications of these discoveries on nutritional value and possible health advantages require additional study.

Enzyme activity and nutritional value of spirulina

The nutritional value of materials, the nutrient content, is a measurable change that occurs when adding spirulina. Since spirulina contains 60–70% protein and jaggery comprises >95% carbs, the prepared foods exhibit a 2-3% increase in proteins and a 2-3% decrease in carbohydrates. This is because 4% of the spirulina was substituted with less jaggery. Cake and bread are examples of foods with a porous structure, characterised by air pockets or cavities that may facilitate enzyme entry and aid in digestion. More surface area is made possible by the porous structure, which improves digestion by exposing more enzymes to the food particles. The matrix of foods with a denser structure, such as peanut balls or some biscuit varieties, may be more compact and firmer. Because it takes longer for enzymes to enter and break down the food particles, this denser structure may cause digestion to proceed more gradually. Figure 2 colour variations illustrate that the food matrix and breakdown occur during processing as a result of the environment's acidity and basicity, as well as the impact of digestive enzymes.

The enzymatic activities (trypsin, pancreatin) in the salt biscuit cause a large release of proteins in the intestinal phase, as seen in Fig. 3(i). The amount of protein released will be limited during the stomach phase, but it will suddenly increase during the intestinal phase. The steady rise in the release of carbohydrates at each stage of digestion is depicted in Fig. 3 (ii). The fibre content of peanuts and wheat reduced the amount of carbohydrates that could be digested in vitro. Foods high in fibre inhibit the release of carbohydrates from their matrix. Fig. 3 (iii) illustrates the carotenoid release during in vitro digestion. The intestinal phase exhibits a massive carotenoid release, while the mouth and stomach phases exhibit a small quantity. In contrast to the carotenoid found in native foods, it is released in small quantities. Food preparation with vegetable oil lowers carotenoid release and micellarization. The enzymatic activity of trypsin, chymotrypsin, and lipase is responsible for the increased phycocyanin release in the intestinal

phase during in vitro digestion, as illustrated in Fig. 3 (iv). Furthermore, the dietary matrix and structure also affect the release. The bioavailability and bio-accessibility of protein, carbohydrates, carotenoids, and phycocyanin in vitro are displayed in Figure 4 (i&ii). The salt biscuit has a greater advantage over cake and peanut balls based on bio-accessibility since it has a high protein bio-accessibility and a low carbohydrate bio-accessibility. Compared to other foods, peanut balls have a higher level of bio-accessibility in terms of carbohydrates and carotenoids. The highest bio-accessibility of phycocyanin, which lessens oxidative stress damage, is found in cake.

Spirulina and its applications

In recent years, microalgae have garnered significant attention due to their nutritional value, composition, and distinctive structure; many species have been utilised as nutritional supplements in the food industry. In this case, in the food industry has also made extensive use of *Spirulina platensis* (SP) because of its high content of acidic polysaccharides and 60% to 70% (dry weight) protein, vitamins (Vitamin C, β-carotene), unsaturated fatty acids (linoleic acid), pigments (chlorophyll a) and micronutrients (sodium, potassium, and calcium), which include a range of important amino acids for the human body [9]. During gastric digestion, SP can keep its spiral shape unaltered. As intestinal digestion proceeds, it can be broken down into short spirals and even granules, which are readily captured by intestinal villi and conformed to the intestinal wall, resulting in passive intestinal selection. In this regard, it was anticipated that SP would be used to increase Resveratrol's bio-accessibility [29]. A stilbene polyphenol, resveratrol (RSV), is found in over 72 plant species across 31 genera and 12 families, including peanuts, berries, and grapes [30]. Jingwen Xu et al. (2024) designed the SP@RSV, which was created by loading RSV into SP via passive diffusion, electrostatic interactions, and hydrogen bonding. This improvement enhanced RSV's capacity to scavenge free radicals, such as OH, O2-, DPPH, and ABTS+, while also enhancing its UV stability by causing proteins and functional groups in SP, including hydroxyl, ester, and unsaturated bonds, to scatter UV light. RSV may interact with digestive enzymes (pepsin, trypsin) and SP polysaccharides during digestion, increasing its bio-accessibility [31].

The majority of nutritional supplements containing spirulina are offered as capsules, tablets, and dry powder. Food aid programs currently offered by organizations like Algama, Phycon, and a few others concentrate on preventing and treating malnutrition, particularly with regard to the requirements of small children who are most at risk. Demand for sophisticated microalgae products is rising as more people look for and attempt to include these microalgae in their daily diets as foods and/or ingredients to improve their health and fend off illness [32]. Spirulina biomass was added to fresh pasta by Rodriguez et al. (2014), improving its nutritional

composition without compromising its cooking, texture, or sensory qualities [33]. Pagnussatt et al. (2014) have also argued that *Spirulina platensis* could be utilized as an ingredient in the production of commercial unusual dry pasta with acceptable sensory and technological qualities [34]. Meanwhile, Deepak Kumar Koli et al. (2022) developed green pasta with nutritional and functional fortification by adding spirulina to the paste, increasing its protein, total phenols, flavonoids, iron, and calcium content, respectively, without influencing its texture or sensation. Supplementing pasta with more than 7.5% spirulina biomass increased its nutritional value and had a greater beneficial impact on antioxidant activity and functional qualities as measured by phenolics and flavonoids [32]. When microalgae were added to pasta, the cooking quality was not impaired, and the textural qualities that are considered acceptable technological features were also preferred.

The main antioxidants that exist in spirulina are phycocyanin, carotenoids, chlorophyll, phenolic compounds, vitamins C and E, and the enzyme superoxide dismutase, which scavenges free radicals. The essential components that the human body requires to maintain healthy functions, calcium, phosphorus, magnesium, iron, and potassium, are likewise abundant in this cyanobacterium. Spirulina is a rich source of γ-linolenic acid (GLA) and essential unsaturated fatty acids (USFA), with a protein concentration of 50-60% [1]. Spirulina's biotechnological applications in the food sector have given rise to several complex challenges, but new developments in genetic engineering, biotechnology, and relevant laws have opened up promising possibilities [35]. Spirulina has a blue-green hue and distinct flavours and scents that most prospective customers dislike. This obstacle necessitates the use of innovative technology in food production to improve the flavour and consistency of products made from spirulina. The rules also exhibit regional discrepancies, which serve as obstacles to market entry due to variations in safety, quality, and labelling standards [36]. To mitigate the extract's strong green hue, enhance its bioavailability, and improve its solubility in proteins and powders, microencapsulation and enzymatic hydrolysis were employed. Patricia Maag et al. (2022) described the final culinary applications, noting that the microencapsulated powder's advantageous particle size distribution (18–29 μm) was achieved through ideal spray drying conditions. For most treated samples, microencapsulation resulted in a noticeably increased denaturation temperature. Encapsulated samples showed a significant reduction in green colour intensity, which was one of the main outcomes. If the protein supply is isolated, that decrease effect will be more pronounced. The results also demonstrated that, in comparison to the untreated samples, enzymatic treatment or encapsulation increases the protein solubility by 10–30% [17]. Numerous scientific studies on both humans and animals have confirmed that spirulina is generally safe to eat. The potential for

usage as a functional food makes spirulina very interesting, but its poor organoleptic qualities further restrict its acceptability and utility among consumers [3]. Thus, the study uncovers a hidden gem of processed, nutrient-sustainable spirulina food that may be investigated for inclusion in daily diet plans as an affordable, healthful way of preventing malnutrition [3].

CONCLUSIONS

The aim of the study was to assess the bio-accessibility and bioavailability of the food products' proteins, carbs, carotenoids, and phycocyanin. Spirulina was successfully added to all three food products, imparting a desirable green hue and structural alterations. The green tint of the cake and peanut balls was darker than that of the salt biscuits. Biochemical research demonstrated variation in nutritional content across different dietary items. The highest protein concentration was found in salt biscuits (18.78 g/100g), followed by cake (10.94 g/100g) and peanut balls (13.34 g/100g). According to carbohydrate measurement, processed foods with wheat and jaggery as ingredients have a high carbohydrate load. Cake had the most carbohydrates (84.64 g/100g), followed by peanut balls (62.24 g/100g) and salt cookies (74.24 g/100g). Additionally, the study assessed the measurement of phycocyanin (5-6.8 mg/g) and carotenoids (higher than 85%). The study's overall conclusions provide light on the bio-accessibility and bioavailability of important nutrients and bioactive substances in foodstuffs incorporating

Chapter 10

A NOVEL IOT FRAMEWORK FOR REAL-TIME FOOD SPOILAGE DETECTION

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ABSTRACT

This study investigated the innovative Internet of Things (IoT) based food spoilage system to design food safety and preservation. The system integrates three distinct gas sensors, MQ4, MQ7, and MQ135, to analyze the environment to detect potential spoilage. The MQ4 sensor specializes in detecting methane (CH_4) levels, a gas commonly associated with decomposing organic matter. By employing MQ4, the system can identify early signs of spoilage in food items, particularly those susceptible to microbial decay. The MQ7 sensor is dedicated to detecting carbon monoxide (CO), a gas emitted during the decay of organic materials. Its inclusion in the system allows for a comprehensive assessment of the storage environment, providing insights into the freshness and integrity of stored food items. The MQ135 sensor serves a multi-purpose role by detecting a range of gases, including ammonia (NH_3), benzene (C_6H_6), and carbon dioxide (CO_2). This sensor broadens the system's capability to identify various spoilage-related gases, offering a more nuanced understanding of the storage conditions. A central Arduino microcontroller processes the data gathered by these sensors in real-time, providing accurate and timely information about the food storage environment. The IoT-based food spoilage detection system enhances food safety and preservation by detecting early signs of spoilage, monitoring them in real-time, and offering remote accessibility. The system's scalability, portability, and user-friendly interface make it a useful tool for a range of applications, helping to improve food safety procedures and decrease food waste in both home and commercial settings.

KEYWORDS

Gas sensors, MQ4, MQ7, MQ135, Arduino processor

INTRODUCTION

In an era of growing urbanization, worldwide trade, and rising demand for perishable foods, guaranteeing the safety and lifespan of food supplies has become a top priority. The problem of food preservation, especially for perishable foods, calls for creative solutions that

combine cutting-edge technology with useful functionality. One of the most important areas of food safety and preservation, due to this requirement, is the creation of technologies for detecting food spoilage. The health of consumers and the sustainability of the economy are seriously threatened by food spoiling, which is frequently brought on by microbial activity, enzymatic reactions, or chemical processes. Food poisoning is a major public health concern that can be caused by bacteria, molds, and other pathogens found in damaged food. Foodborne illnesses, which can range from moderate gastrointestinal discomfort to serious infections, can result from consuming rotten food. Extreme foodborne illness instances can lead to hospitalization or even death, especially in susceptible groups like children, the elderly, and people with compromised immune systems [1].

Food businesses and customers alike bear a heavy financial burden from food deterioration. Consumers lose money when food spoils because they have to throw away tainted goods or pay for medical care if they get a foodborne illness. Food spoilage causes revenue losses, resource waste, and decreased profitability for companies involved in the food supply chain, such as farmers, manufacturers, distributors, and retailers. These financial losses can have wider effects and add to the food system's inefficiencies. in areas with little access to fresh food sources. Incidents involving food rotting may lead to regulatory inquiries and enforcement measures to guarantee adherence to food safety guidelines. Companies that are proven to be careless in preventing food deterioration or wilfully sell tainted goods risk fines, legal action, and harm to their reputation [2]. Establishments found to be accountable for outbreaks of food-borne illness may face penalties, recalls, or even closures from regulatory bodies, underscoring the significance of strict food safety protocols. Therefore, the consequences of food spoiling in public include health hazards, financial losses, food insecurity, environmental damage, a decline in trust, and legal repercussions.

The network of physical objects, or "things," that are equipped with sensors, software, and other technologies to connect and exchange data with other systems and devices via the Internet is known as the Internet of Things (IOT). As a result of the confluence of several technologies, including real-time analytics, machine learning, commodity sensors, and embedded systems, the concept of the Internet of things has changed. The Internet of Things is made possible by a number of traditional fields, including automation (including home and building automation), wireless sensor networks, control systems, and embedded systems. Conventional approaches to food storage condition monitoring, which depend on manual examination or crude indications, are prone to errors and inefficiencies [3]. As a result, there is an urgent need for sophisticated technologies that can identify and reduce spoiling hazards instantly. The emergence of Internet of

Things (IOT) technology has transformed a number of sectors by providing previously unheard-of capabilities in remote communication, data collection, and analysis. Food rotting detection systems have developed to use specialised sensors, microcontrollers, and connection solutions by utilising the Internet of Things. This allows for proactive alerting and accurate monitoring in a variety of storage conditions.

This study presents a novel Internet of Things (IoT)-based food deterioration detection system intended to handle the challenges of contemporary food preservation. By combining cutting-edge gas sensors, such as MQ4, MQ7, and MQ135, this system provides a thorough method of real-time gas monitoring linked to spoiling. Every sensor is designed to identify particular gases linked to food breakdown, giving users useful information about the state of goods that are being stored. An Arduino microcontroller, the system's central processing unit, decodes sensor data and enables smooth connectivity with other devices. Accessibility and promptness in monitoring storage conditions are guaranteed by an intuitive interface that includes a 16x2 LCD display. A loud alarm notifies users when spoiling is detected, allowing for fast action to reduce hazards and food waste. Additionally, the system uses a GSM modem to leverage cloud connectivity, allowing for remote management and monitoring through the Thing Speak server. Through SMS notifications, customers' mobile devices receive real-time information on storage conditions, enabling proactive action and well-informed decision-making. Food safety and preservation have increased significantly owing to this system's integration of cutting-edge sensor technology and Internet of Things capabilities. Its real-time spoiling risk detection capabilities, along with its remote monitoring and warning features, enable users to efficiently protect food resources in a world that is becoming more linked and complicated. Food security, waste reduction, and a sustainable food supply chain are all potential outcomes of ongoing innovation and integration in food rotting detection systems.

The following aims were undertaken in the current endeavor to solve the aforementioned knowledge gaps: (1) To enhance Food safety and develop an Internet of Things (IOT) based system, (2) To monitor and implement a central Arduino microcontroller, (3) To create a user-friendly interface and incorporate a 16×2 LCD display, (4) To establish cloud connectivity and establish communication, and (5) To implement the SMS notification via the GSM modem.

MATERIALS AND METHODOLOGY

In this present investigation, an Internet of Things (IoT) based food spoilage detection system is designed to enhance food safety and preservation. The several parts of the sensors are interconnected and continuously monitor and report the condition of food goods in an Internet of Things (IOT)-based food spoilage detection system. The sensors at the centre of the system

identify a number of factors, including temperature, humidity, gas emissions (such as ethylene), and microbial activity, that are suggestive of food spoiling. A microprocessor or microcontroller attached to these sensors processes the received information. After processing, the data is sent to a cloud-based server via wireless communication modules (such as Wi-Fi, Bluetooth, or cellular networks). In Figure 1, the server uses algorithms to aggregate and evaluate the data in order to determine the food's level of spoiling. An online or mobile application that offers real-time notifications and information on the food's freshness gives users access to this data. The system can also be integrated with a database to save historical data, allowing for predictive maintenance and trend analysis. All things considered, the block diagram in Figure 1 shows how information flows smoothly from the sensors to the end users, guaranteeing prompt and precise spoiling detection.

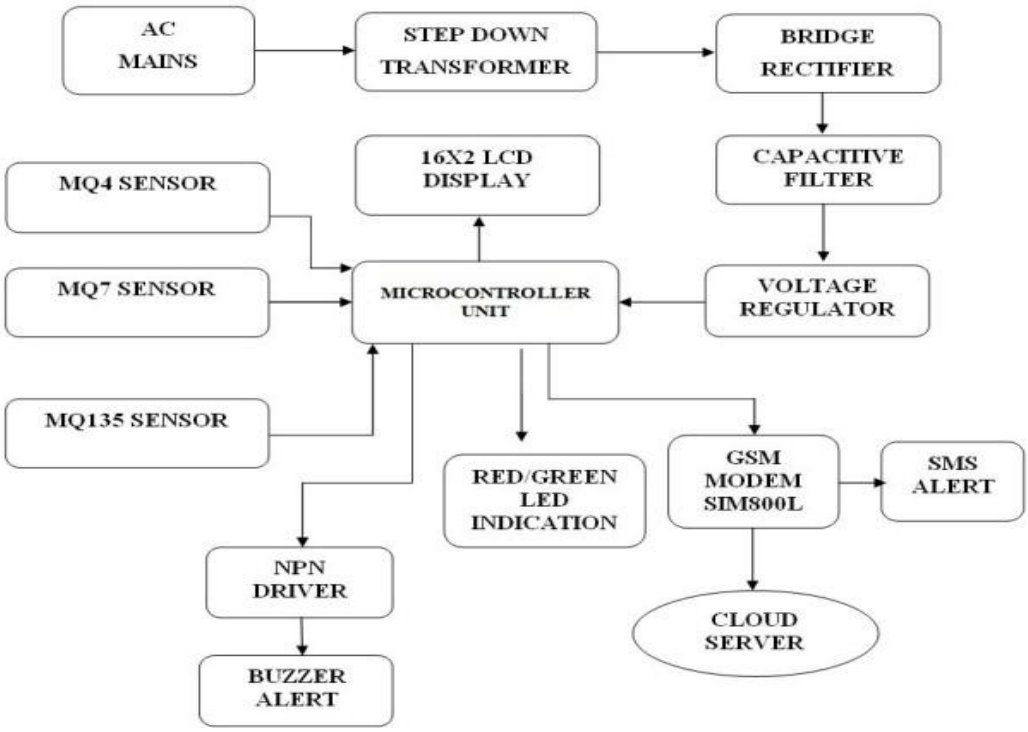


Figure.1: The flowchart of the IoT-based food detection system block diagram

SENSOR MATERIALS

Transformers

The power supply voltage will be stepped down by the potential transformer from 0–230V to 0–6V. The precision rectifier, which is built with the aid of an operational amplifier, will next be

connected to the secondary of the envisioned transformer. Precision rectifiers have the advantage of providing a DC peak voltage output, which the remaining circuits will provide. It is a mains transformer with a general-purpose chassis mounting. The transformer contains centre-tapped secondary windings and 240V primary windings. Flying colored insulated connecting lines (about 100 mm in length) are included with the transformer. The transformer reduces AC 240V to AC 12V by acting as a step-down transformer. Power supplies for circuit boards and various projects. Reduce 230 V AC to 12 V while maintaining a maximum current of 1 Amp. Transformers can be used to change the AC voltage, current, and waveform in circuits. A transformer is a crucial component of electronic devices. Transformers transform and commutate power supply equipment to nearly reach AC and DC voltage. A transformer is an electrical device that uses electromagnetic induction to move electrical energy between two or more circuits. When a conductor is exposed to time-varying magnetic fields, electromagnetic induction creates an electromotive force. utilized in electric power applications to modify the alternating voltages [5]. The secondary winding of this step-down transformer is larger than the main winding. It can step down the voltage because of this winding. A transformer uses two electrical qualities to convert electricity from high to low voltage or between high and low voltage. A conductor subjected to time-varying magnetic fields generates an electromotive force by electromagnetic induction. It is utilised to modify the alternating voltages in applications involving electric power [6]. A transformer is a crucial component of electronic devices. Transformers transform and commutate power supply equipment to nearly reach AC and DC voltage (Figure 2).

Bridge Rectifier

The circuit is known as a bridge rectifier when four diodes are linked as in the figure. The circuit's input is applied to the network's diagonally opposed corners, while the output is extracted from the other two corners. Assume that point A has a positive potential and point B has a negative potential, and that the rectifier is operating effectively. Bias D3 will be forwarded, and bias D4 reversed by the positive potential at point A. Point B's negative potential will reverse D2 and forward bias D1. Since D4 and D2 are currently reverse-biased, current flow will be blocked through them, but D3 and D1 are forward-biased and will let current flow through them [7].

Voltage Regulator

As shown in Figure 2, regulator IC modules combine the circuitry for overload protection, a com amplifier, and a reference source. The power ratings of the regulators range from milliwatts to tens of watts, and they can be chosen to operate with load currents ranging from hundreds of milliamperes to tens of amperes. From 5 to 24 volts, the series 78 regulators offer fixed positive

regulated voltages. From 5 to 24 volts, the series 79 regulators offer set negative regulated voltages. An uncontrolled DC input voltage, Vi, is applied to one input terminal of a fixed three-terminal voltage regulator, while a regulated DC output voltage, Vo, is obtained from a second terminal, and the third terminal is grounded. From 5 to 24 volts, the series 78 regulators offer fixed positive regulated voltages. A similar range of fixed negative regulated voltages, from 5 to 24 volts, is offered by the series 79 regulators. 5 volts for LCDs and IC microcontrollers. 12 volts for relay circuits, op-amps, and alarm circuits [8].

Microcontroller

An open-source initiative called Arduino developed kits based on microcontrollers for creating interactive objects and digital gadgets that can sense and manage real-world objects. The project is based on designs for microcontroller boards that use different microcontrollers and are made by many manufacturers. These systems offer sets of analog and digital input/output (I/O) pins that can connect to other circuits and expansion boards, often known as shields. To load applications from personal computers, the boards provide serial communication interfaces, including Universal Serial Bus (USB) on certain variants. Microcontrollers are programmed. offers an integrated development environment (IDE) built on the Processing programming language, which is compatible with C and C++. The ATmega328P serves as the foundation for the Arduino Uno microcontroller board. It features a 16 MHz quartz crystal, 6 analogue inputs, 14 digital input/output pins (six of which can be used as PWM outputs), a USB port, a power jack, an ICSP header, and a reset button. It has all the components required to support the microcontroller; just use a USB cable to connect it to a computer or an AC-to-DC adapter to power it [9]. Numerous features allow the Arduino Uno to communicate with other microcontrollers, another Arduino board, or a computer in Figure 2.

Liquid Crystal Display

A liquid crystal display is referred to as LCD. They are available in a variety of sizes, including 8x1, 8x2, 10x2, 16x1, 16x2, 16x4, 20x2, 20x4, 24x2, 30x2, 32x2, 40x2, and more. Numerous global corporations, including Philips, Hitachi, Panasonic, and others, manufacture unique LCDs for use in their products. All LCDs carry out the same tasks, such as displaying ASCII characters, numbers, special characters, and other characters. All have the same 14 pins (0–13) or 16 pins (0–15), and all have the same programming. Numerous devices, such as Fig. 2 palmtop computers, word processors, photocopiers, point-of-sale terminals, medical devices, cell phones, etc., use alphanumeric displays. This LCD display was made specifically for E-blocks. A single 9-way D-type connector is attached to the LCD display, which has 16 characters and two lines of alphanumeric characters. This makes it possible to connect the device to the majority of E-

Block I/O ports. Data in a serial format is needed for display; the user manual below explains this. Additionally, a 5V power source is needed for the display. Please be careful not to exceed 5V, as this will damage the gadget. The E-blocks Multi programmer or a 5V static regulated power supply are the best sources of 5V. It is possible to display 224 distinct characters and symbols on the 16 x 2 intelligent multilingual dot matrix displays [10]. The whole list of characters and symbols is listed on pages 7/8; keep in mind that these symbols can differ depending on the LCD brand being utilized. This pamphlet contains all the technical details needed to connect the device, which needs a single power source (+5V).

SIMCOM GSM Modem

The GSM modem is compatible with SIM cards from any GSM network operator, exactly like a cell phone with a unique number. The ability to communicate and create embedded applications using this modem's RS232 connection is a benefit. This makes it simple to create applications like data transfer, SMS control, remote control, and logging. The modem can be linked to any microcontroller via MAX232 or straight to a PC serial port. It is capable of making and receiving voice calls as well as sending and receiving SMS. Additionally, it may be used in GPRS mode to connect to the internet and run a variety of data logging and control programs. Additionally, you can connect to any distant FTP server in GPRS mode and upload. The GSM Modem accepts any GSM network as a SIM card and functions comparable to a mobile phone, with its own unique phone number. Using this modem has the benefit of allowing you to communicate and create embedded applications via its RS232 interface. The SIM800CS is a quad-band device that operates on frequencies of GSM850MHz and provides performance for voice, SMS, data, and fax in a small form factor and with low power consumption (Fig.2). The SIM800C is a full dual-band GSM/GPRS solution in an SMT module with an industry-standard interface [11].

MQ4 SENSOR

A gas sensor module called the MQ4 sensor was created especially to identify methane (CH_4) gas in the ambient air. It works on the basis of semiconductor conductivity, which states that when methane gas is present, the sensor's resistance changes. A tiny circuit board with a semiconductor gas sensor at its centre usually makes up the MQ4 sensor module. Its power supply and signal output connections make it simple to integrate into a variety of electrical systems. Because of its small size and low weight, the sensor module can be used in both stationary and mobile applications. The MQ4 sensor is ideal for applications requiring methane level monitoring, as its primary function is to detect methane gas in the environment. The rapid response time of the MQ4 sensor enables prompt methane gas detection and timely notifications in the event of leaks or other

dangerous circumstances. Methane emissions from agricultural practices, landfills, and other sources that contribute to greenhouse gas emissions can be measured using it in environmental monitoring systems. The sensor helps to prevent accidents and guarantee worker safety by detecting methane leaks in underground mines, confined spaces, and other dangerous locations. To improve domestic safety, MQ4 sensors are included in gas detection systems in homes to notify residents of possible leaks from natural gas pipelines, propane tanks, or other gas appliances, as shown in Fig. 2. According to Sumit et al. (2020), MQ4 sensors are employed in industrial settings for process control and monitoring in applications such methane gas generation, storage, and transportation. Methane gas might serve as a warning sign for combustion or fire. To provide an early warning of fire threats in high-risk areas, such as industrial facilities, MQ4 sensors are used in fire detection systems [12].

MQ7 Sensor/ QMC Sensor

A gas sensor module called the MQ7 sensor is made to identify carbon monoxide (CO) gas in the ambient air. It works on the basis of semiconductor conductivity, which states that when carbon monoxide gas is present, the sensor's resistance changes. A tiny circuit board with a semiconductor gas sensor at its centre usually makes up the MQ7 sensor module. It makes integrating into other electronic systems simple. The sensor module is appropriate for both static and mobile uses due to its small size and low weight. Methane emissions from agricultural practices, landfills, and other sources that contribute to greenhouse gas emissions can be measured using it in environmental monitoring systems. The sensor serves to prevent disasters and promote worker safety by detecting methane leaks in limited spaces in underground mines (Fig. 2) and other hazardous situations [13].

MQ135 Sensor

A gas sensor module called the MQ135 is made to identify a number of gases in the atmosphere, such as carbon dioxide (CO_2), benzene (C_6H_6), and ammonia (NH_3). Typically, the MQ135 sensor module consists of a semiconductor gas sensor housed on a tiny circuit board. It has power supply and signal output connections. It is lightweight, small, and appropriate for both fixed and mobile use. The MQ135 sensor is versatile for a range of gas detection applications since it can detect numerous gases, such as carbon dioxide, benzene, and ammonia. Because of its high sensitivity to the target gas, the sensor can identify even minute levels of the gas in the atmosphere. It is suitable for a range of applications, from industrial safety systems to air quality monitoring, due to its broad detection range for various gases. Because of its short response time, the MQ135 sensor can identify target gases quickly and provide timely alarms in dangerous situations. Since the sensor module uses little power, it is energy-efficient and appropriate for

battery-powered gadgets or applications where power consumption is an issue (Fig.2). With its simple interface and power input and analogue output connections, the MQ135 sensor module makes it simple to integrate into electrical systems [14]. Sensors are applied in industrial safety systems to identify dangerous gases in manufacturing operations, chemical factories, and other hazardous settings, assuring worker safety.

Buzzer

An auditory signalling device, such as a buzzer or beeper, can be piezoelectric, mechanical, or electromechanical. Buzzers and beepers are commonly used for timers, alarm devices, and user input confirmation, such as keystrokes or mouse clicks. A buzzer is a DC power supply and electronic transducer that is commonly found in computers, printers, copiers, alarms, electronic toys, automobile electronics, telephones, timers, and other electronic devices that produce sound. The board and the sensor expansion module in this part can be used to complete a basic circuit design that allows you to "plug and play." The active buzzer with a 5V rated power may be connected directly to a continuous sound [15].

An auditory signalling device, such as a buzzer or beeper, can be piezoelectric, mechanical, or electromechanical. Buzzers and beepers are commonly used for timers, alarm devices, and verifying user input, such as a keystroke or mouse click. By just supplying D.C. voltage, it produces a steady single-tone sound. When high sound levels are required, this type can be employed with a properly constructed resonant system. Figure 2 shows that Future Electronics stocks several of the most common varieties, which are classified by Type, Sound Level, Frequency, Rated Voltage, Dimension, and Packaging Type [16].

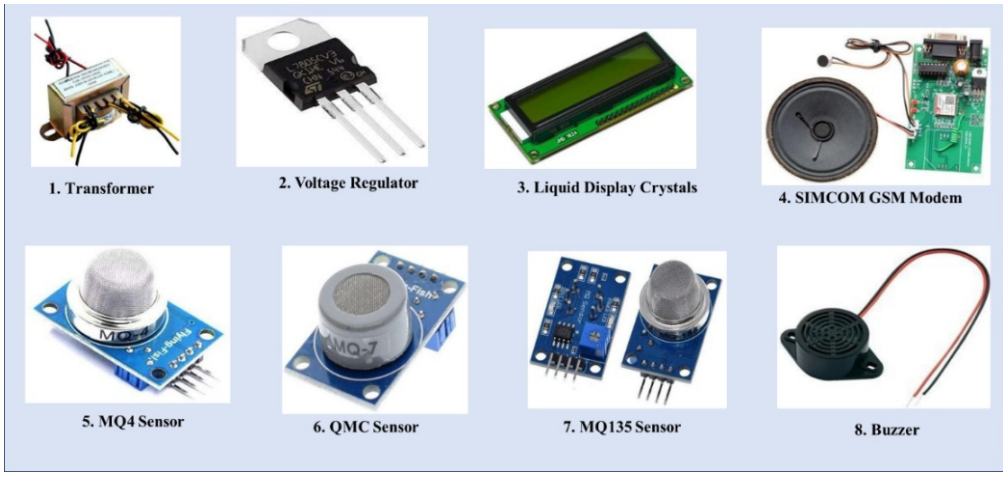
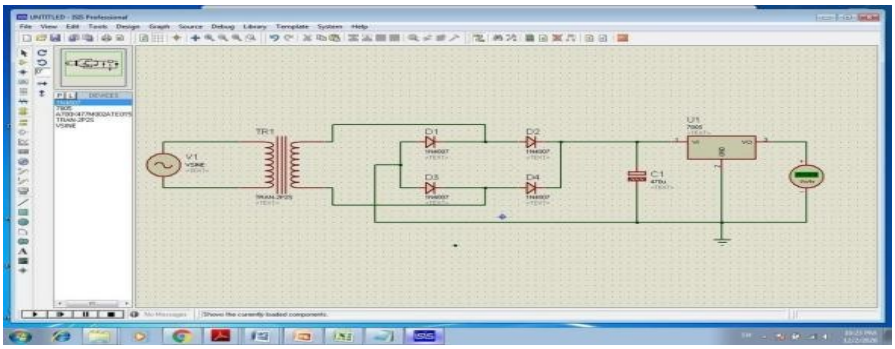


Figure 2: Sensor Materials

Power Supply

An embedded circuit known as a regulated power supply transforms uncontrolled alternating current (AC) into a steady DC. It transforms the AC supply into DC with the aid of a rectifier. Its purpose is to provide a circuit or device that needs to be run within specific power supply constraints with a steady voltage (or, less frequently, current). In Figure 3, the output from the regulated power supply is almost always DC (Direct Current), though it can also be alternating or unidirectional [17]. The stabilization method can be limited to making sure the output stays within specific bounds under different load scenarios, or it can additionally compensate for changes in its own supply source. The latter is now far more prevalent.



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Figure 3: Think Speak Cloud Server

RESULTS AND DISCUSSION

Analysing IoT-based detection

The system employs a number of gas sensors, including MQ4, MQ7, and MQ135, to detect a wide range of spoilage-related gases such as methane, carbon monoxide, ammonia, benzene, and carbon dioxide. Early identification of possible spoiling signs is made possible by this multi-sensor technique, which offers a thorough evaluation of the storage environment. Real-time processing of the sensor data by a central Arduino microcontroller enables precise and prompt food storage environment monitoring. By enabling proactive intervention to stop spoiling, this real-time processing guarantees that users receive instant updates on the state of food products that are stored. GSM modem connectivity is incorporated throughout the system to facilitate communication with cloud-based servers, including the Thing Speak server. The food storage environment can be remotely monitored and managed from any location at any time, thanks to this cloud connectivity. When spoiling occurs, users can take immediate corrective action since they can access real-time data and obtain notifications on their mobile devices [18]. A 16x2 LCD panel displays key information about the storage environment,

including gas levels and signs of deterioration. Making educated decisions is made easier by this user-friendly interface, which lets consumers quickly check the status of food items that are stored. An audio alarm is set off to notify consumers to act right away if the product is spoiled. In order to ensure that users are promptly alerted to spoiling events and can take the appropriate corrective action, the system also uses the GSM modem to send SMS notifications to predetermined mobile numbers. Because of its scalable and adaptable design, the suggested system can be easily integrated with current infrastructure and used in a variety of locations and environments. Customization and expansion according to particular needs and preferences are made easier by the modular architecture. Because of its minimal maintenance and cost-effective design, a broad spectrum of users can utilize the system. Using open-source software frameworks and off-the-shelf components reduces the cost of both initial installation and continuing maintenance [19]. All things considered, the suggested system provides a complete Internet of Things-based solution for efficient food deterioration detection and notification. Through the use of cutting-edge sensor technologies, real-time monitoring tools, and remote management features, the technology enables users to enhance food safety, reduce waste, and make informed decisions about preserving stored food.

Output of the Sensor

Advanced sensors, data analytics, and connectivity are used by Internet of Things-based food spoilage detection systems to track the quality and freshness of food items in real time. To identify environmental changes that point to spoiling, these systems usually use a combination of gas sensors, temperature and humidity sensors, and occasionally even optical sensors [20]. Through the use of IoT technology, these sensors gather data, which is then sent to a central platform for analysis using machine learning algorithms to forecast spoiling and notify users. In addition to guaranteeing food safety and improving supply chain efficiency, this real-time monitoring greatly reduces food waste. By offering precise, timely information that can be vital for both consumers and businesses, these systems have the potential to completely transform the food industry, according to discussions around them. IoT and blockchain integration is also being investigated to improve food supply chain traceability and transparency, which would add still another degree of dependability and trust. The cost of execution, the requirement for standards, and guaranteeing data security and privacy are the primary issues raised. However, IoT-based food spoilage detection systems are becoming increasingly popular worldwide due to advantages including longer product shelf lives, lower financial losses, and better public health [21]. Food safety and preservation have improved with the use of the IoT-based food spoilage

detection system that incorporates MQ4, MQ7, and MQ135 sensors (Fig. 4). The system's performance and ramifications led to the following main conclusions and discussions.

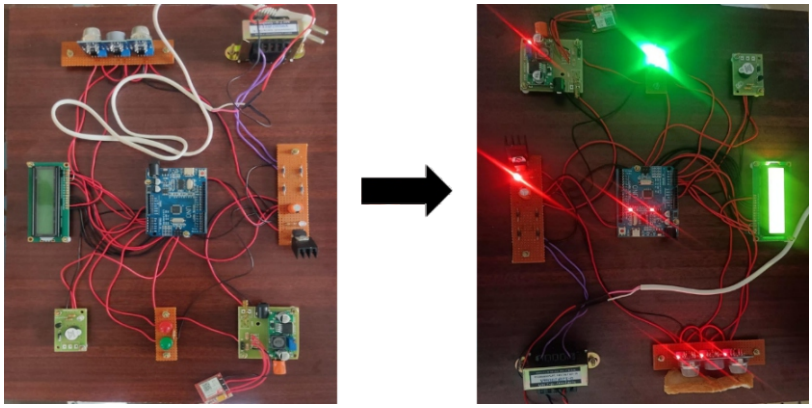


Figure 4: Output of IoT-Based Food Spoilage design

Early Detection of Spoilage Indicators

Early identification of rotting signs in the food storage environment has been made possible by the integration of MQ4, MQ7, and MQ135 sensors. Early indicators of organic matter breakdown were successfully detected by the MQ4 sensor, which specialises in measuring methane levels. This was especially true for perishable foods that are vulnerable to microbial degradation (Corradini et al., 2022). In a similar vein, the MQ7 sensor, which is used to detect carbon monoxide emissions, enhanced the MQ4 sensor's detection capabilities by offering information about the integrity and freshness of food products that are stored. Additionally, the system's ability to detect different gases linked to spoiling was expanded by the MQ135 sensor's multi-gas detection capability, providing a more sophisticated understanding of the storage conditions [23].

Versatility and Adaptability

The system's modular design, which included MQ4, MQ7, and MQ135 sensors, provided flexibility and adaptability to a range of conditions. Due to its scalability, the system might be expanded and customized to meet the demands of different users, such as families, commercial facilities, and small-scale food producers, depending on their own tastes and requirements. Additionally, the system was positioned as a reliable solution for efficient food spoilage detection and warning in technologically advanced societies through the integration of cutting-edge sensor technologies and IoT frameworks. The IoT-based food spoilage detection system enhances food safety and preservation by detecting early signs of spoilage, monitoring them in real-time, and offering remote accessibility [24]. The system's scalability, portability, and user-friendly interface make it a useful tool for a range of applications, helping to improve food safety procedures and

decrease food waste in both home and commercial settings. Optimizing sensor performance, improving data processing algorithms, and extending the system's ability to handle new issues in food safety and preservation could be the main goals of future research and development [25].

CONCLUSION

The integration of MQ4, MQ7, and MQ135 sensors into an IoT-based food spoilage detection system has shown notable progress in improving food safety and preservation procedures. The system provides a strong solution for proactive intervention and decision-making through remote accessibility, real-time monitoring, and early detection of spoiling signs. The system has the potential to be widely adopted in a variety of industrial and household settings due to its user-friendly interface, adaptability, and versatility. This would increase food safety, decrease food waste, and improve people's quality of life in general. The system's performance can be improved and its capabilities expanded to handle changing food safety and preservation concerns with more research and development.

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Chapter 11

DEVELOPMENT OF PROTEIN BASED ANTIMICROBIAL MATERIAL FOR PACKAGING APPLICATION

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ABSTRACT

The creation of novel, biodegradable packaging materials is becoming increasingly significant in the modern era. Packaging materials made from protein help lessen the damage that synthetic polymers contribute to the environment. In this study, the protein was extracted from the hemp seed using centrifugation and changing the pH. The packaging film was developed using the solution casting method. After that, the film was examined for a variety of characteristics, such as protein estimation, antibacterial and antioxidant qualities. Compared to the standard protein film, the antimicrobial packaging film demonstrated better mechanical, antibacterial, and optical qualities. The application of the antimicrobial films showed that dry fish packed in normal packaging spoiled faster with greater changes in pH, weight loss and hardness than the dry fish packed in antimicrobial film. The incorporation of pepper mint oil in the film prevented the lipid oxidation due to the antioxidant activity of phenolic compounds present in pepper mint and resulted in lower peroxide values.

KEYWORDS

Biodegradability, antimicrobial packaging, hemp seed, pepper mint oil, dry fish

INTRODUCTION

Packaging is a critical aspect of food manufacturing, designed to preserve food quality during storage, transportation, and consumer use. Its primary functions include safeguarding against biological, chemical, and physical deterioration, extending shelf life, and ensuring food safety [1,2]. Packaging also contributes to marketing, traceability, and portion control [3]. In recent years, the environmental impact of synthetic packaging materials has led to a rise in interest for biodegradable films. These alternatives offer biodegradability, biocompatibility, and a wide range of potential applications, addressing growing concerns over plastic pollution [4,5].

Biodegradable films are primarily made from biopolymers like proteins, polysaccharides, and lipids, which are used in the production of eco-friendly food packaging [6]. The blending of biodegradable polymers with additives, including plant extracts, can enhance packaging properties such as mechanical strength, barrier function, and antioxidant or antimicrobial properties [7]. These plant-based extracts, rich in phenolic compounds, improve food safety and shelf life by offering natural antioxidant and antimicrobial protection [8]. This trend toward using plant extracts in packaging reflects an increasing demand for natural additives in food products. Biodegradable films made from such extracts are seen as an effective means of ensuring food safety while meeting environmental sustainability goals [9].

Cannabis sativa, or hemp, is one such plant gaining attention in the food packaging industry. Hemp has long been used for various purposes, including textile fibers and medicine, and its seeds are recognized as nutritionally complete, rich in proteins, lipids, and essential fatty acids like omega-3 and omega-6 [10,11]. The protein content of hempseed, particularly the globulin edestin, has nutritional significance due to its high digestibility and low anti-nutritional factors, making it a promising protein source for infant nutrition [12,13]. Hemp protein can also serve as a potential additive in biodegradable films, improving their properties [14].

The extraction of proteins from hempseed is a critical process in the development of biodegradable films. Various methods, including refrigeration and liquid nitrogen, are used to preserve protein integrity during extraction [15]. Gelatin, another important biopolymer derived from collagen, is also widely used in food packaging due to its water-binding ability, film-forming capacity, and flexibility [16]. Gelatin films are often enhanced with additives to improve mechanical stability and barrier properties, making them suitable for food packaging [17]. However, gelatin's brittleness and poor elongation require the use of plasticizers to improve its flexibility and toughness [18]. These plasticizers work by reducing intermolecular forces in the polymer chains, allowing for better flexibility and toughness [19].

Another significant development in food packaging is the use of peppermint oil, extracted from the leaves of Mentha piperita, for its antimicrobial and antioxidant properties. Peppermint oil has been found to have potent activity against a range of microorganisms, including bacteria like *Escherichia coli and Salmonella typhimurium* [20,21]. Its antimicrobial properties are particularly useful in extending the shelf life of packaged food by inhibiting microbial growth, thus preserving both food quality and safety [22]. Peppermint oil also contains menthol, which provides a cooling sensation and has potential applications in food, pharmaceutical, and cosmetic products [23]. The synergistic effect of peppermint oil with other antimicrobial agents can further enhance its efficacy in food packaging [24].

The food preservation methods used for fish, such as drying and salting, highlight the importance of packaging in maintaining product quality. Dried fish, a key product in the global market, retains its nutritional quality and offers an affordable food option in many regions [25]. However, fish is highly perishable and prone to microbial spoilage. Sun drying and salt curing are traditional methods employed to prevent spoilage and extend shelf life [26]. Microbial spoilage in fish products caused by bacteria such as *Staphylococcus spp., E. coli, and Vibrio spp.,* significantly impacts quality and safety [27]. Thus, effective packaging and preservation techniques are necessary to reduce physical and microbial losses, and improve product value.

Drying and salting techniques used in fish preservation are economically beneficial, especially for low-value species. These methods ensure that dried fish can be stored and transported over long distances while maintaining its nutritional content, including essential fatty acids and micronutrients [28]. The nutritional composition of dried fish, rich in proteins, omega-3 fatty acids, vitamins, and minerals, contributes to its role in alleviating malnutrition, especially in developing countries [29,30]. However, microbial contamination remains a concern during the drying process, necessitating the use of effective packaging solutions to prevent spoilage and extend shelf life [31].

In this study, the development of biodegradable food packaging materials, enhanced by natural additives like plant extracts, hemp proteins, peppermint oil, and biopolymers such as gelatin, represents an important step toward sustainability in the food industry. The use of such materials addresses environmental concerns while also improving food safety and shelf life. As consumer awareness of the ecological impact of synthetic packaging grows, the demand for biodegradable alternatives is expected to increase, driving further research into the development of more efficient and functional food packaging solutions. These innovations promise not only to protect food products but also to contribute to the broader goal of reducing environmental pollution caused by plastic waste.

MATERIALS AND METHOD

SAMPLE COLLECTION AND PREPARATION

Ingredients like hemp seeds, peppermint oil, dry fish, and gelatin were purchased from Merck and the local market. Prior to being ground using a mortar and pestle, the hemp seed was first kept in a freezer at 4°C for a full day in order to precipitate high protein. For one hour, the dry fish was gently dried.

FILM PREPARATION

5 g of gelatin was measured and taken and it was then mixed with 100 mL of distilled water, and the mixture is heated to 100°C. After heating, 1 mL of peppermint oil and 2 mL of glycerol was added to the solution. The mixture was allowed to slightly cool down before 3 g of hemp protein was added and mixed thoroughly. Finally, the solution was poured into petri plates and allowed to dry for approximately 24 hours.

PROTEIN EXTRACTION

The extraction procedure was followed in accordance with the technique described by [32]. Several batches were prepared, then pooled and mixed before further use. Seeds were washed twice and left at room temperature at 25°C for 1 day to reduce the saponin content [33]. A rotating mill (Retsch, ZM 300, Haan, Germany) was used to grind the seeds into fine flour with a particle size of <0.5 mm. The resulting flour was collected in plastic bags that were sealed and stored at 4°C until protein extraction by sequential precipitation. The obtained flour and distilled water were combined at a ratio of 1:10 (w/v). The slurry was stirred using a digital magnetic stirrer (JoanLab, SH-4, Fristaden Lab, NV, USA) and its pH was adjusted to pH 9.5 using NaOH (0.1 M). Stirring (1,000 rpm) was continued for 2 h at 40°C with pH monitoring every 30 min, followed by centrifugation (Kubota, S700TR, Tokyo, Japan). The supernatant was obtained, acidified to pH 4.2 with HCl (0.1 M), then kept overnight before centrifugation. The precipitate was collected and lyophilized (Büchi, R-220, Flawil, Switzerland). The crude protein content of the lyophilized protein (61.78% ± 2.10) was determined using the AOAC Method 930.29, N × 6.25 (AOAC, 2012). The lyophilisate was ground, placed in plastic bags, sealed, and stored at 4°C further use.

ANTIMICROBIAL ACTIVITY

The microorganisms of gram positive strains such as *Staphylococcus aureus* as well as gram negative strains such as *Escherichia coli* and *Pseudomonas aeruginosa* were used for the evaluation of antimicrobial activity. Tetracycline was chosen as the standard reference. The controls consist of solidifying agar onto which was solvent, and the test compounds were soluble in it. The test was performed in nnutrient agar medium under in an aseptic condition. The nutrient agar medium was prepared and autoclaved according to the standard methods. The hot medium was poured in sterile Petri plates which were kept in the aseptic laminar chamber. The medium was allowed to solidify for 15 minutes.

Agar well diffusion method is widely used to evaluate the antimicrobial activity of plants or microbial extracts [34,35]. Similarly to the procedure used in disk-diffusion method, the agar plate surface is inoculated by spreading a volume of the microbial inoculum over the entire agar surface. Then, a hole with a diameter of 6 to 8 mm is punched aseptically with a sterile cork borer or a tip, and a volume (20–100 mL) of the antimicrobial agent or extract solution at desired concentration is introduced into the well. Then, agar plates are incubated under suitable conditions depending upon the test microorganism. The antimicrobial agent diffuses in the agar medium and inhibits the growth of the microbial strain tested.

INVITRO ANTIOXIDANT ASSAYS

1) DPPH RADIAL SCAVENGING ACTIVITY

The radical scavenging activity of different samples was determined by using DPPH assay according to [36]. The decrease in the absorption of the DPPH solution after the addition of an antioxidant was measured at 517nm. Ascorbic acid (10 mg/mL DMSO) was used as reference. 0.1mM DPPH solution was prepared by dissolving 4 mg of DPPH in 100 mL of ethanol. Different volumes (2 - 20µl) of sample were made up to 40 µL with DMSO and 2.96 mL DPPH (0.1mM) solution was added. The reaction mixture was incubated in dark condition at room temperature for 20 min. After 20 min, the absorbance of the mixture was read at 517 nm. 3 mL of DPPH was taken as control. The % radical scavenging activity of the plant extracts was calculated using the following formula,

% of DPPH radial inhibition = [Control – Sample] /Control × 100

2) PHOSPHOMOLYBEDENUM REDUCTION ASSAY

The antioxidant activity of samples was evaluated by the green phosphomolybdenum complex formation according to the method of [37]. Reagent was prepared by adding 0.588 mL of sulphuric acid, 0.049 g ammonium molybdate and 0.036 g sodium phosphate. The final volume was made up to 10 mL with distilled H_2O. 10 mg of sample was dissolved in 1 mL of DMSO. 100 µL from the prepared sample was taken and 1 mL of reagent solution was added to it and incubated in a boiling water bath at 95°C for 90 min. After 90 min, the absorbance of the solution was read at 695 nm. Ascorbic acid (10 mg/mL DMSO) was used as standard. The Phosphomolybdenum reduction potential (PRP) of the studied sample were reported in percentage.% of phosphomolybdenum redyuction = [Control – Sample] /Control × 100

SHELF LIFE TEST

Shelf life testing is a critical facet of food quality control, intricately connected to various aspects of food testing and analysis. This rigorous process involves assessing the duration during which a food product can uphold its intended quality and safety standards. In the quest for

accurate results, shelf life testing often intertwines with microbiological analysis, ensuring that the product remains free from harmful microorganisms throughout its defined lifespan. Furthermore, it delves into the realm of nutritional analysis, tracking changes in essential nutrients to guarantee that the product's nutritional facts align with labelling claims. For those with allergenic concerns, shelf life testing also plays a role in monitoring allergen content, assuring consumers that their safety remains a priority. Thus, this multifaceted testing approach is instrumental in providing consumers with products that are not only safe but also maintain their quality and nutritional value over time. Shelf life studies are used to determine the shelf life of a product by subjecting it to conditions that accelerate the aging process. These studies simulate the effects of normal storage conditions on a product, but in a shorter period of time, allowing manufacturers to make predictions about the product's stability, safety, and quality over its entire shelf life.

TOTAL PLATE COUNT (TPC)

This study microbiological quality analysis was carried out using total plate count method. Total Plate Count (TPC) is a method of estimating the total microorganism number (mold, yeast, bacteria) in an ingredient. TPC analysis uses Plate Count Agar (PCA) as media by planting one gram of diluted sample into petri dish, and then incubated. TPC calculation result is presented as colonies (cfu)/mL. The tools used include: test tubes, stomacher, petri dish, Erlenmeyer, micropipette, bunsen, incubator, autoclave, refrigerator, analytic scales, spatulas and stirring rod. The stages begin from tools sterilization using autoclave with a temperature of 121ºC for 45 minutes. In the homogenization stage, 5 g of sample is mashed using a stomacher then added to 85% as much as 45 mL. In this stage obtained 10-1 dilution, then the dilution stage was carried out as much as 10-5 by providing a test tube 9 mL containing of 85% NaCl. Then fill the tube by taking 10-1 dilution sample as much as 1 mL to get a sample suspension tube with 10-2. From 10-2 tube 0.1 mL was taken to be inserted into the next tube until a sample suspension is obtained with 10-5 dilution. Then PCA media was poured into 15-20 ml. After the PCA is frozen, 0.1 mL of dilution sample is taken into a petri dish and leveled with a stirring rod. The final stage is incubation by inserting all petri dishes in the upside position into the incubator. Incubation is carried out at 37 ^{o}C for 24-48 hours. Calculation and recording of colony growth is carried out in colony forming unit per mL (cfu/ ml) or per gram (cfu/ml) [38]. Total microbial analysis was carried out by taking 1 mL of each dilution sample and put it in a sterile petri dish. Then liquid PCA media is poured into the petri dish as much as 15-20 ml. Petri dishes are carefully rotated and moved horizontally or parallel (or form an eight) until the sample is evenly mixed. At the same time a blank check is also carried out by mixing the buffer into the media. The mixture in the next petri dish is allowed to freeze. The final stage is incubation by inserting all

petri dishes upside down into the incubator. Incubation was carried out at 36 ± 1°C for 24-48 hours. Calculation and recording of colony growth is carried out in colony units forming units per gram or ml of sample (cfu / gr or ml) [39].

PROTEIN ESTIMATION

A rapid and accurate method for the estimation of protein concentration is essential in many fields of protein study. An assay originally described by Bradford (Bradford 1976) has become the preferred method for quantifying protein in many laboratories. This technique is simpler, faster, and more sensitive than the Lowry method. Moreover, when compared with the Lowry method, it is subject to less interference by common reagents and nonprotein components of biological samples. The Bradford assay relies on the binding of the dye Coomassie Blue G250 to protein. Detailed studies indicate that the free dye can exist in four different ionic forms for which the pKa values are 1.15, 1.82, and 12.4 [40]. Of the three charged forms of the dye that predominate in the acidic assay reagent solution, the more cationic red and green forms have absorbance maxima at 470 nm and 650 nm, respectively. In contrast, the more anionic blue form of the dye, which binds to protein, has an absorbance maximum at 590 nm. Thus, the quantity of protein can be estimated by determining the amount of dye in the blue ionic form. This is usually achieved by measuring the absorbance of the solution at 595 nm. The dye appears to bind most readily to arginyl and lysyl residues of proteins [41]. This specificity can lead to variation in the response of the assay to different proteins, which is the main drawback of the method. The original Bradford assay shows large variation in response between different proteins [42-44]. Several modifications to the method have been developed to overcome this problem. However, these changes generally result in a less robust assay that is often more susceptible to interference by other chemicals. Consequently, the original method devised by Bradford remains the most convenient and widely used formulation. Two types of assay are described here: the standard assay, which is suitable for measuring between 10 and100 µg of protein, and the microassay, which detects between 1 and 10 µg of protein.

RESULT AND DISCUSSION

PROTEIN EXTRACTION

Proteins were extracted from the hemp seed as highlighted by [45] reveals Water kefir fermentation significantly improved the digestibility of the LP-QP complexes from 76.43% before fermentation to 85.31% on Day 3 and then to 87.25% on Day 5. The fermenting microorganisms in water kefir produce a variety of enzymes, including proline-specific peptidases, exopeptidase, and intracellular peptidases, which can contribute to the breakdown of large protein assemblies into oligopeptides and then smaller peptides and amino acids [46]. Moreover, the linkages (e.g.,

amide, ether, and ester bonds) between nutrients (e.g., proteins, lipids, and carbohydrates) and non-nutrient components such as phenolic compounds, tannins, and saponins are also susceptible to cleavage by microbial enzymes [47]. Protein unfolding as the pH decreases promotes access of the enzymes to their cleavage sites. These enzymatic reactions decrease the molecular weight of the protein assemblies and modify the biological and physicochemical properties of fermented proteins [48].

ANTIMICROBIAL ACTIVITY

1) ANTIMICROBIAL ACTIVITY OF HEMP SEED

The ethanol extract of hemp seed were investigated for invitro antimicrobial activity against microorganism including gram positive bacteria (*Staphylococcus aureus*) negative bacteria (*Escherichia coli* & *Pseudommonas aeruginosa*) as research finding from [49]. The antimicrobial sensitivity of the hemp seed extract and their potency where assessed quantitatively by measuring the diameter of clear zone in cultures in thin plates shown in the Fig. 1. The hemp seed have greater antimicrobial properties against these three microorganisms by analysing the Table 1 under three different concentrations of hemp seed. The antimicrobial activity may be due to the presence of secondary metabolites such as phenolic compounds, terpenoids, tannin, alkaloids affect the growth of microbes.

2) ANTIMICROBIAL ACTIVITY OF PEPPERMINT OIL

The similar procedure was followed for the ethanol extract of peppermint oil. It was investigated for invitro antimicrobial activity against microorganism including gram positive bacteria (*Staphylococcus aureus*) and negative bacteria (*Escherichia coli & Pseudommonas aeruginosa*) as shown in the Fig. 2 and Table 2. The antimicrobial activity may be due to the presence of secondary metabolites such as phenolic compounds, terpenoids, tannin, alkaloids affect the growth of microbes.

3) ANTIMICROBIAL ACTIVITY OF PACKAGING FILM

Fig. 3 depicts the antimicrobial activity of the ethanol extract of packaging film. It was investigated the invitro antimicrobial activity against microorganism including gram positive bacteria (Staphylococcus aureus) and negative bacteria (*Escherichia coli & Pseudommonas aeruginosa*) (Table 3). The antimicrobial activity may be due to the presence of secondary metabolites such as phenolic compounds, terpenoids, tannin, alkaloids affect the growth of microbes.

ANTIOXIDANT TEST FOR INGREDIENTS

1.DPPH TEST FOR HEMP SEED

Determination of antioxidant activity was assessed by DPPH assay as reported [36]. For that, the six different concentrations of ethanol extract of hemp seed are mixed with 1µL of DPPH solution and that are incubated at dark room for 30 minutes. The absorbance is read at 517 nm in the spectrometer. The analysis of data from table 4 reveals, the antioxidant activities increases with increasing concentration of DPPH indicates the hemp seed has the potential to inhibit the oxidation reaction (Fig. 4).

2.DPPH TEST FOR PEPPERMINT OIL

The research finding from [36] reveals that, the six different concentration of ethanol extract of peppermint oil are mixed with 1µL of DPPH solution and that are incubated at dark room for 30 minutes. The absorbance is read at 517 nm in the spectrometer. The analysis of data from Table 5 reveals, the antioxidant activities increases with increasing concentration of DPPH indicates the peppermint oil has the potential to inhibit the oxidation reaction (Fig. 5).

ANTIOXIDANT TEST FOR PACKAGING FILM

1.DDPH TEST FOR PACKAGING FILM

To evaluate the antioxidant activity of packaging film, the six different concentration of ethanol extract of packaging film are mixed with 1µL of DPPH solution and that are incubated at dark room for 30 minutes [36]. The absorbance is read at 517 nm in the spectrometer. The analysis of data from Table 6 reveals, the antioxidant activities increases with increasing concentration of DPPH indicates the packaging film has the potential to inhibit the oxidation reaction (Fig. 6).

2.PHOSPHOMOLYBEDNUM TEST FOR PAKAGING FILM

Antioxidant activity of packaging film also evaluated by phosphomolybednum assay as reported [37]. For that, the six different concentration of ethanol extract of packaging film are mixed with 1µL of Phosphomolybednum solution and that are incubated at dark room for 30 minutes. The absorbance is read at 695 nm in the spectrometer. The analysis of data from Table 7 reveals, the antioxidant activities increases with increasing concentration and reached 85.33% at120 µg/ml indicates the packaging film has the potential to inhibit the oxidation reaction as one of characteristics needed for packaging application (Fig. 7).

TOTAL PLATE COUNT – TPC

The research finding reveals that total plate count provide the actual numerical value of the total plate count obtained from the sample [38]. This value presents the total number of viable microorganisms per unit volume or weight of the sample (e.g CFU/mL or CFU/g) (Table 8). 1 mL of 10^{-5} sample solution is spread over the agar plate and incubates for 24 hours. The analysis of the

data from Fig. 8 reveals total microorganisms present in the sample tested over 3rd, 5th and 7th days.

PROTEIN ESTIMATION

The estimation of protein was performed by generating the standard curve using known concentration [50]. The absorbance of the standard solution is measured at different concentrations, and a plot of absorbance versus concentration is obtained. This allows for the determination of the protein concentration in the sample based on absorbance. This concentration is usually expressed in units such as milligrams per milliliter (mg/ml) or micrograms per microliter (μg/μl), depending on the volume of the sample used.

By analysing the Table 9 the concentration protein present in the hemp seed are 20 (mg/ml) as per the protein standards (Table 10).

SHELF LIFE TEST

The shelf life of the dry fish was tested by coating the film solution over the dry fish for 1 week in the normal room temperature. During this period there is no oxidation, microbial growth, rancidity and odorness over dry fish. The coated dry fish remains fresh during this time period as compared to the normal dry fish indicates the prepared film has potential to increase the shelf life the dry fish (Fig. 9).

SIGNIFICANCE OF PREPARED FILM

This protein based antimicrobial packaging film has greater advantage over film used for packaging of dry fish. Because this film have antioxidant, antimicrobial property as it will fight against the microorganisms that developed during the storage and transportation due to the pheonolic content present in the peppermint oil. The film covered dry fish produce less odour, greater strength of packaging ability when compared to the other normal packaging film. This film can be used for the export of dry fish to other country due to their antimicrobial activity (Fig. 10).

CONCLUSION

. This study explored the development of an antimicrobial packaging film reinforced with hemp seed protein and peppermint oil for dry fish packing and biodegradability. The antimicrobial films showed excellent antimicrobial activity against *E. coli*, *Staphylococcus aureus* and *pseudomonas* because of bioactive components in the peppermint oil. In addition, the film has superior antioxidant properties when compared to existing packaging films made of proteins. The application of the films was done using dry fish because there is no proper packaging material for dry fish. The shelf life analysis proved that the dry fish packed in the antimicrobial film had more shelf-life when compared with those packed in pure protein films. The changes in weight loss, pH, hardness and peroxide value were less pronounced for dry fish packed in antimicrobial films

because of the antioxidant and antimicrobial properties of the peppermint oil. Hence, the developed film is suggested for delaying oxidation and improving the antimicrobial activity of meat products.

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Chapter 12

BIOMARKERS DERIVED FROM EXOSOMES FOR EARLY CANCER DIAGNOSIS

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ABSTRACT

Early cancer identification is essential since the primary objective is to lower cancer-related deaths globally. Exosomes, a subgroup of EVs released by virtually all cell types, have been the focus of growing research as potential bearers of diagnostic information. These nanosized vesicles are laden with a heterogeneous molecular cargo comprising RNAs, DNAs, proteins, lipids, and metabolites, reflecting the physiological or pathological state of their cells of origin. Tumor cells release exosomes into the blood, so they can be used as an easy and minimally invasive method to detect cancer early through simple body-fluid tests. The current study summarizes exosome biology, assesses their potential as a novel medium for early cancer diagnosis, and evaluates the essential isolation and analytical techniques, as well as the most critical translational and clinical studies. This review has focused on recent methodological advances, new standard guidelines such as Minimal Information for studies of extracellular vesicles 2023, and increasing evidence for their clinical application. It also succinctly describes the key challenges, including test variability, difficulty finding tumour-specific markers, regulatory approval, and high costs. Finally, it offers clear recommendations for future research and emphasizes that exosome-based liquid biopsies have strong potential to improve early detection and personalized treatment of cancer.

KEYWORDS:

Early detection, Exosomes, Biomarkers, Liquid biopsy, cancer biology

INTRODUCTION

Exosomes are secreted naturally by nearly all cells and have been found in almost all biological fluids, including plasma, saliva, etc (Vlassov, A.V. et al., 2012). Exosomes are biologically remarkable because their lipid bilayer membrane encapsulates and protects the

molecular cargo they carry-proteins, lipids, and all the nucleic acids, such as DNA, mRNA, lncRNA, etc. and metabolites from enzymatic degradation. This sturdy structure enables exosomes to survive adverse conditions, travel long distances, and reliably deliver information between cells (Di Bella, M. A. et al., 2022). The most effective strategy in cancer-related treatment is the diagnosis of early cancer. For most tumours, prognosis is stage-dependent: localised or organ-confined tumours are usually amenable to curative treatments like surgery or targeted therapy. At the same time, advanced-stage cancers often show poor therapeutic responsiveness and outcomes (Sunela, K. et al., 2013). Early detection can be considered a cornerstone of modern oncology and preventive medicine (Loomans-Kropp, H. A., & Umar, A. et al., 2019). Whereas traditional diagnostic approaches have involved tissue biopsies, imaging modalities, and serum biomarkers, these approaches have inherent limitations (Neagu, A. N. et al., 2025). Tissue biopsies are invasive and often difficult or impossible to repeat; thus, they may not reflect tumour heterogeneity (Gilson, P et al., 2025). Imaging techniques are obviously potent but have resolution thresholds beyond which they cannot detect microscopic or even early lesions (McDonald, D. M et al., 2003). Serum biomarkers, such as CA19-9 or PSA, are useful in some cancers but most often lack the sensitivity or specificity required for universal early detection (Skulimowski, A. et al. 2021). These limitations have spurred the development of liquid biopsy technologies to detect tumour-derived materials circulating in readily accessible biofluids such as blood, urine, or saliva (Soda et al., 2022).

Among liquid biopsy analytes, ctDNA, CTCs, and EVs have garnered particular attention (Wang, X. et al., 2024). While the successes of detecting tumour-specific mutations using ctDNA-based assays are well-documented, these approaches are usually hampered by the low abundance of ctDNA in early-stage disease (Chin, R. I. et al., 2019). Detection of CTCs is informative yet technically challenging and usually lacks the potential for population-scale screening (Obaro, A. E et al., 2018). In this context, exosomes, a subclass of small extracellular vesicles with dimensions between 30 and 150 nm, have emerged as a compelling alternative and complement to existing liquid biopsy methods (Liang, Y. et al., 2021). Moreover, exosomes are not mere passive cellular debris but are actively formed through endosomal pathways involving the invagination of multivesicular bodies and the selective loading of molecular content (Di Bella, M. A. et al., 2022). This active sorting mechanism ensures that exosomes reflect the physiological or pathological status of the parent cells (Wei, H. et al., 2021). In the context of cancer, tumour cells reprogram their exosomal content to favour the transfer of oncogenic molecules, thereby driving tumour growth, angiogenesis, immune evasion, and metastasis (Yang, E. et al., 2020). Such active molecular curation imparts a diagnostic fingerprint to

exosomes, enabling them to distinguish malignant states from their standard physiological counterparts (Xiang, Z. et al. 2023).

Another advantage lies in their greater abundance and accessibility: tumour cells are known to secrete exosomes at rates significantly higher than those of some normal cells, thus amplifying tumour signals even when the overall tumour burden is small (Kharaziha, P. et al., 2012). Hence, exosome-associated biomarkers can be detected at earlier stages of the disease when standard ctDNA or CTC assays may fail to register measurable signals (Soda, N et al., 2019). Because exosomes can be isolated noninvasively from biofluids, repeated sampling for longitudinal disease monitoring becomes feasible and patient-friendly (Li, J., Wang, A., et al., 2025).

Despite its promise, clinical translation of exosome biology for early detection faces many challenges (Rezaie, J et al., 2022). Among these, there is a need to overcome technical variability in exosome isolation and heterogeneity among vesicle populations, as well as to distinguish between tumour-derived and commonly derived exosomes. (Willms, E. et al., 2022). From exosome isolation to data analysis, one should follow strict standards to ensure reliable, reproducible results (Chowdhury, P. R. et al., 2025). However, as more studies come to light highlighting the potential of exosome-based diagnostics, their utility for early cancer detection becomes clearer (Wang, Y. et al., 2021). It will have created a potential future in which the integration of multi-omic exosomal data—putting together RNA, DNA, and protein signatures—with modern computational models might enable early and precise cancer detection using a simple blood or urine test (Hussen BM et al., 2025). Continued advances in exosome isolation technologies, biomarker discovery, and clinical validation are rapidly moving this vision from concept to clinical reality (Ansarian, M. A. et al., 2025).

MATERIALS AND METHODS

Biological Overview of Exosomes

EVs are mainly grouped into ectosomes and exosomes. Exosomes are tiny vesicles that form within the endosomal system of eukaryotic cells and typically range from 40–160 nm, averaging about 100 nm. They form within Multivesicular bodies through the inward budding of endosomal membranes. When these MVBs fuse with the plasma membrane, the intraluminal vesicles are released into the extracellular space as exosomes. Some studies say that exosomes are likely involved in the removal of excess constituents to maintain cellular homeostasis (Raghu Kalluri et al, 2020). Through various molecular mechanisms, the cargo of exosomes is actively and selectively sorted. Specific proteins and nucleic acids are loaded into these vesicles by

means of the ESCRT system. Other pathways, including proteins such as tetraspanins, lipid rafts, and RNA-binding proteins, also guide this selection process. Hence, exosomes do not contain random material from the cell but carry a selected set of molecules representative of the functional state of the cell (Lee, Y.J. et al., 2024).

TDEs carry harmful molecules, including mutant KRAS DNA, abnormal miRNAs, and tumour antigens. This helps the tumour grow through facilitating new blood vessel formation, evading the immune system, and spreading to other sites. Due to the overexpression of specific genes, some of which are involved in growth and invasion, different groups of tumour cells develop within the tumour microenvironment. These sub-clones can also release vesicles showing chromosomal deletions associated with metastatic disease. Consequently, cancer cell-derived vesicles have been classified as either small oncosomes, with a size range of 100–400 nm, or large oncosomes, with sizes between 1–10 μm, depending on their size and content. Thus, studying tumour-derived vesicles may provide important insights into cancer molecular features and heterogeneity (Papadopoulos, K.S. et al., 2025).

CLASSES OF EXOSOME-DERIVED BIOMARKERS

Non-Coding RNAs (miRNAs, lncRNAs, and circRNAs)

ExomiRs are microRNAs enclosed within exosomes and are under extensive investigation as cancer biomarkers. miRNAs, at the post-transcriptional level, regulate gene expression and are typically dysregulated in malignant cells. Because the lipid bilayer of exosomes protects these miRNAs from degradation, they can be reliably detected in plasma, serum, or other fluids. (Salehi M et al., 2024). Many studies have shown that exosomal miRNA patterns can clearly distinguish patients with cancer from healthy individuals. For instance, miR-21 and miR-1246 are frequently highly expressed in cases of breast and other pancreatic-related cancers, while miR-1290 is highly expressed in colorectal cancer. Generally, diagnostic accuracy is increased when a panel of multiple exosomal miRNAs, rather than a single marker, is used (Jafari A. et al, 2023). The recent additions to the exosomal biomarker classes are lncRNAs (long non-coding RNAs) and circRNAs (circular RNAs). These molecules participate in gene regulation and cellular signalling, and other expression patterns. Exosomal lncRNA H19 and circRNA 0001785 have shown diagnostic potential in hepatocellular carcinoma and breast cancer, respectively. Such RNA-based signatures are foreseen to complement protein- and DNA-based markers in comprehensive diagnostic panels (Wang R, Xu Y. et al., 2024).

Exosomal Proteins and Surface Markers

Another primary class of exosomal biomarkers consists of proteins. It carries many proteins that are differentially expressed in tumours, such as luminal and surface proteins. The tetraspanins, integrins, and tumour-associated antigens such as HER2 or EGFR are common surface markers. (Akbar et al., 2022). *Immuno-capture* is a process in which antibodies specific to tumour antigens isolate cancer-derived exosomes from mixed plasma samples. The surface markers are valuable because they enable immuno-capture. For example, the glypican-1 (GPC1)–positive exosome subset has been explored as a marker of pancreatic cancer (Poellmann MJ et al., 2020). Protein biomarkers provide functional insights into tumour physiology, including post-translational modifications and signalling activities. Analytical methods such as mass spectrometry and ELISA facilitate both the discovery and validation of these protein targets, supporting their translation into clinical assays (Barker AD et al., 2023).

Exosomal DNA (Exo-DNA)

Point mutations, copy-number variations, and methylation alterations are examples of it. These double-stranded DNA fragments can be encapsulated in exosomes and represent the mutational profile of the original tumor. The aforementioned DNA has an advantage over freely flowing DNA because it is shielded from enzymatic degradation by the vesicle (Xiang Z. et al., 2024). High-sensitivity analytical methods, such as digital PCR, duplex sequencing, and targeted next-generation sequencing (NGS), enable the detection of rare variants in exosomal DNA. Studies to date suggest that exo-DNA could complement cfDNA analysis by improving overall sensitivity for identifying low-burden or early-stage disease (Jet, T. et al., 2021).

Lipids and Metabolites

Lipidomic and metabolomic studies in exosomes represent relatively new areas of investigation. Cancer cells alter their metabolic pathways, and thus the lipid composition of exosomes derived from cancer cells differs from that of normal cells (Zebrowska, A. et al, 2019). Alterations in molecules such as phosphatidylserine, sphingomyelin, and cholesterol-related lipids are associated with cancer (Li, C., Wang, et al., 2023). Integration of lipid and metabolite profiles with RNA and protein markers has excellent potential to enhance cancer diagnosis further and may also identify different tumour subtypes, although the techniques are technically quite challenging (Cutshaw, G, et al, 2023).

RESULT AND DISCUSSIONS

Current Trend in Exosome-Derived Biomarkers

Multi-omic biomarker discovery is the identification of biomarkers using multi-omics approaches, such as proteomics, transcriptomics, lipidomics, and metabolomics, to analyse

exosome content and discover more precise cancer biomarkers (Al-Daffaie FM., et al., 2025). This method is helping to develop more reliable diagnostic models by integrating multiple molecular layers (Wen, Caining MSa., et al., 2025). Noncoding RNAs, such as exosomal miRNAs, remain among the most studied biomarker groups. Reviews highlight their role in cancer diagnosis, prognosis, and cell-to-cell communication. (Ghani Muhammad Usman et al, 2025). Several miRNAs, such as miR-21, miR-155, and miR-1246, are expressed in many types of cancers. A study in Nanobiotechnology presented a panel of exosomal miRNAs, including miR-21, miR-155, miR-10b, and others, which have demonstrated great diagnostic accuracy.

Isolation and Analytical Techniques

Accurate measurement of exosomal biomarkers requires reproducible isolation and pre-analytical processing. Several variables, namely centrifugation speed, storage conditions, and isolation method, may significantly affect the output. MISEV 2023 provides clear, unified guidelines on how to produce, isolate, and characterize Extracellular Vesicles (EVs). All of these standards emphasise detailed reporting of metadata and transparent methodology to enhance reproducibility (Kurian T K et al., 2021).

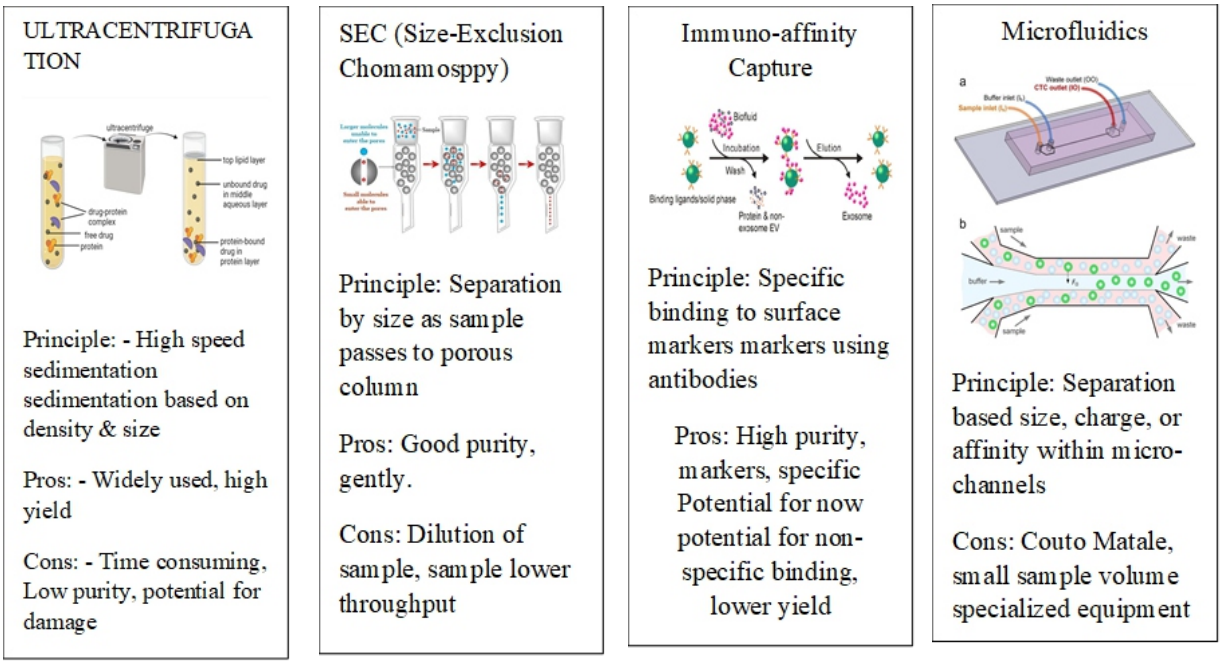


Figure 1: Exosome Isolation Method Comparison

The standard methods of isolation include differential ultracentrifugation (DUC), which uses a series of high-speed centrifugations to separate exosomes based on size and density. Size-Exclusion Chromatography, which uses porous beads to separate particles by size. Polymer precipitation, often using polyethene glycol (PEG), is also widely used for its simplicity. However, it may yield less pure

samples than immunoaffinity capture, which uses antibodies to bind specific exosomal surface proteins. The method of isolation would depend on the type of downstream analyses (RNA, protein, or DNA) and the clinical purpose. For translational applications, automation and regulatory compliance are essential.

Isolation Method	Principle	Advantage	Limitations	Suitability for clinical use
Ultracentrifugation	Density-based separation	Widely used, low-cost	Time-consuming, low-purity	Moderate
Size-Exclusion Chromatography	Size-based filtration	Gentle, good purity	Diluted samples	High
Immunoaffinity capture	Antibody-based capture	High specificity	Expensive, may miss subtypes	High
Polymer precipitation	Polymer-based precipitation	Easy, fast	Co-precipitates contaminants	Low-Moderate

Table 1: Comparison of Exosome Isolation Methods

Analytical Platforms

Exosomes transport a broad range of biomolecules, the composition of which reflects their cell of origin, whether in a normal or diseased state (Kalluri R. et al., 2020). Because tumour cells secrete exosomes even at very early stages of disease, the contents of these vesicles can serve as highly sensitive indicators of early cancer (Théry C. et al, 2018). Each of the major types of exosomal cargo-RNAs, DNA, proteins, lipids, and metabolites, represents key targets in the development of minimally invasive diagnostic technologies (Xu R. et al, 20218). The sections that follow describe the analytical methodologies and diagnostic utility for each cargo type in the context of early cancer detection (Zhang X. et al, 2015).

Exosomal RNA Analysis

Exosomes carry various types of RNA, including miRNAs, mRNAs, lncRNAs, and circRNAs. Due to protection by the vesicle's lipid membrane, these RNAs stay very stable (Hosseini, K., et al, 2022). Since early-stage cancer cells exhibit distinct RNA patterns, exosomal RNA is among the most widely studied biomarkers (Zhu M et al., 2024). Different analytical methods study exosomal RNA. qRT-PCR is common because it is simple and yields reliable detection of cancer-specific RNAs (Bellingham SA et al., 2017). Digital droplet PCR achieves even higher sensitivity, enabling accurate measurement of minimal amounts of RNA, which is important for early cancers where tumour material may be limited (Wang C et al., 2019). NGS provides a

broad, unbiased view of all RNA species, which helps identify new biomarkers and establish multi-RNA diagnostic panels (Hosseini, K. et al., 2022).

Exosomal DNA Analysis

There is also a relatively novel and highly effective biomarker modality in exosomes: double-stranded genomic DNA (exo-DNA; Ghosh S. et al., 2024). Exo-DNA reflects the genomic landscape of its original tumor cells, including point mutations, copy-number variations, and epigenetic alterations such as DNA methylation (Soung YH, et al, 2017) Given that tumor-derived exo-DNA is detectable even at early disease stages, it represents a minimally invasive means for the identification of molecular events associated with early carcinogenesis (Yang S, et al 2017).

Many different analytical platforms are utilised in Exo-DNA profiling (Wang ZY et al, 2020). Highly sensitive and specific mutation detection, especially for recurrent driver mutations such as TP53 and KRAS, is enabled by digital PCR (Ghoreyshi N et al, 2025). Targeted NGS panels allow simultaneous screening of a wide range of oncogenes and tumour suppressor genes. At the same time, duplex sequencing enables the detection of uncommon mutations emerging in the early stages of malignant transformation due to its extremely low error rate (Xiong K. et al., 2022). Whole-genome sequencing can also be utilized for the detailed assessment of structural variants and mutational burden (Tang H., et al, 2024).

Exosomal Lipidomics

Among the first biochemical changes in tumour cells are lipid abnormalities; these reflect changes in membrane dynamics, energy metabolism, and cellular signalling pathways. LC-MS/MS is the technique of choice for exosomal lipid profiling, providing high-resolution identification and quantification of lipid species. Other supporting analytical tools include vibrational spectroscopic techniques, such as FTIR and Raman spectroscopy, which monitor structural changes in lipids via vibrational modes, and MALDI-TOF MS, which enables rapid lipid fingerprinting.

Exosomal Protein Analysis

Proteins represent another prominent group of exosomal cargo with high value for cancer diagnosis. Tumour-derived exosomes contain specific surface and internal proteins that reflect early cancer-related changes, including well-known cancer markers such as EpCAM, EGFR, HER2, and PD-L1, common exosomal proteins like CD9, CD63, and CD81, and stress

proteins like Hsp70 and Hsp90 (Kalluri R. et al, 2020). Changes in these protein levels can indicate early tumour development even when no tumour is yet detectable (Mashouri L. et al, 2019). Several technologies are used to analyse exosomal proteins. LC-MS/MS offers a broad, unbiased view into the complete protein profile. **(Greening D.W. et al. 2015)** Whereas ELISA enables targeted detection of selected protein markers, Luminex assays can measure several proteins simultaneously. On the other hand, flow cytometry and nano-flow cytometry are increasingly being applied to single-vesicle analysis of proteins; these techniques help distinguish tumour-derived exosomes from those released by normal cells (**Tian Y. et al., 2020).**

Exosomal Metabolomics

Exosomal metabolomics is the study of tiny molecules carried by exosomes that represent early metabolic changes in cancer, including modifications to the TCA cycle, lipid processing, glycolysis, and amino acid metabolism (Zhang et al., 2020). Important analytical techniques include mass spectrometry-based metabolomic systems, which enable the sensitive identification of extremely low quantities of metabolites, and NMR spectroscopy, which offers great precision and repeatability (Clos-Garcia et al., 2018). Using these instruments, scientists have discovered unique metabolic patterns associated with the initial stages of cancer (Wei et al., 2022).

Biomarker Type	**Examples**	**Clinical Relevance**	**Cancer Types Studies**
miRNAs	miR-21, miR-1246	Early detection & prognosis	Pancreatic, lung, colorectal
lncRNAs	HOTAIR, MALAT1	Tumor progression markers	Breast, gastric
circRNAs	circ-PDE8A	Invasion & metastasis markers	Pancreatic
Proteins	Integrins, EGFR	Surface markers for capture	Lung, liver
exo-DNA	Mutant KRAS, TP53	Mutation detection	Pancreatic, colorectal

Table. 2: Classes of Exosomal Biomarkers and Their Diagnostic Significance

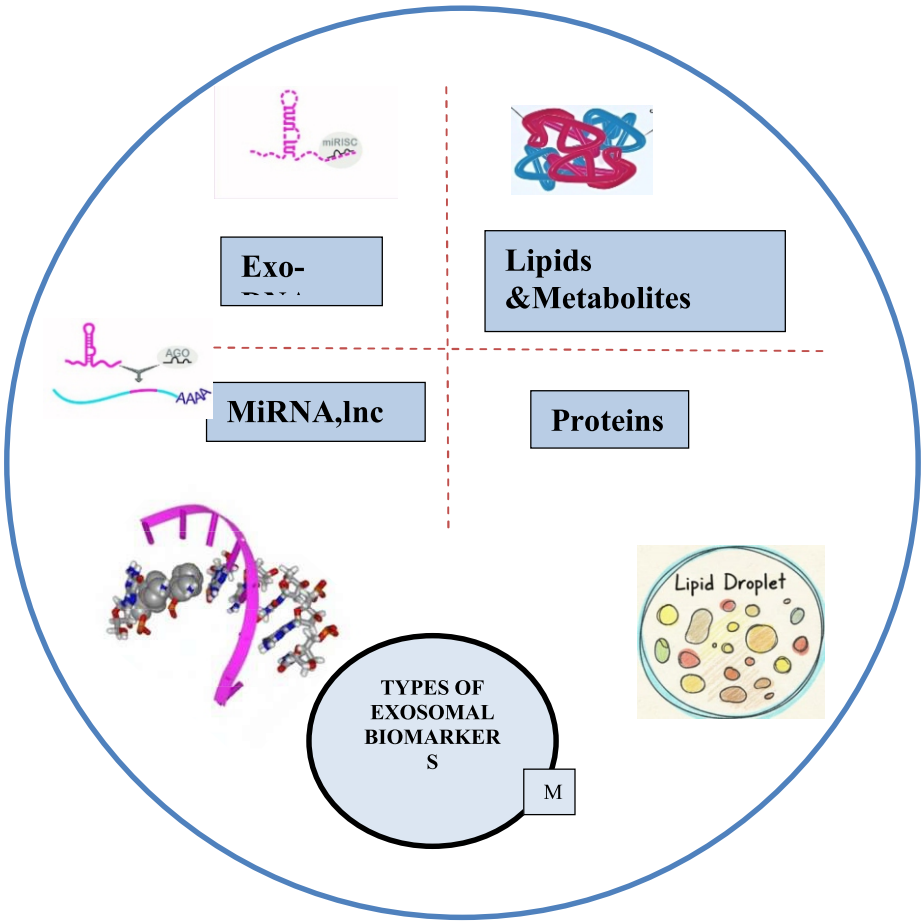


Figure 2: Exosomes Biomarkers

Pancreatic Cancer

One of the best illustrations of the potential of exosome-based diagnostics is pancreatic cancer. The sensitivity of standard biomarkers, such as CA19-9, is insufficient to identify early-stage disease (Locker et al., 2020). Combining an exosome-based molecular test with CA19-9 significantly increased the diagnosis of stage I–II pancreatic cancer, according to a multicenter study presented at AACR 2024 (Buscail et al., 2024). Patients who would otherwise have gone unnoticed but had surgically curable malignancies were identified using this combination approach (Melo et al., 2015). Even though the results are encouraging, further prospective research is still required to validate their therapeutic utility (Costa-Silva et al., 2015).

Gastric, Liver, Lung, and Colorectal Cancers

Several case-control studies have identified exosomal miRNA and protein panels that can help distinguish early-stage cancer patients from healthy individuals across different tumour types (Yang B et al, 2024). For example, exosomal miR-423-5p and miR-451a are linked to lung and gastric cancers, respectively. In contrast, exosomal GPC1 and specific integrin signatures show

diagnostic promise in colorectal and liver (hepatocellular) cancers (Li, J. et al, 2017). Despite these advances, results still vary widely between studies due to differences in sample handling, study design, and analytical platforms. As a result, prospective multicenter trials are now being planned to standardize methodologies and validate these biomarkers in real-world clinical conditions (Jiang, K., et al, 2020).

Cancer Type	Study/Year	Biomarker Type	Key Findings
Pancreatic	AACR 2024	Exosomal proteins + CA19-9	Improved stage I–II detection
Gastric	Sui et al., 2025	exomiRs	High sensitivity in early-stage disease
Hepatocellular	Behulová et al., 2023	miRNA panels	Differentiated HCC vs controls

Table 3: Review of cancer types and biomarker types

CHALLENGES TO CLINICAL TRANSLATION

Several significant challenges must be addressed before exosome-derived biomarkers can be adopted for routine screening and early detection.

Biological heterogeneity

The content of exosomes, including proteins, RNAs, and lipids, is often very heterogeneous due to the different types of cancer, the tumor microenvironment, and even patient-specific factors. This heterogeneity complicates the detection of broadly reliable, universal biomarkers. (Théry et al., 2018). There are no fully harmonized protocols concerning the isolation, quantification, or characterization of exosomes. Various isolation techniques, such as ultracentrifugation, size-exclusion chromatography, and immunoaffinity capture, often give inconsistent results, reducing reproducibility across different studies (Li et al., 2017). Therefore, extensive, well-designed clinical studies are needed to confirm the diagnostic accuracy and sensitivity of exosome-based assays across diverse patient populations. Mostly, regulatory agencies need to clearly detail pathways for approval of emerging diagnostic technologies (Kalluri et al, 2020).

Scalability and workflow integration

Clinical laboratories face a real challenge in integrating these exosome-based multi-omics approaches into existing systems, particularly given the need for cost-effective, high-throughput workflows suitable for routine clinical use (Xu et al., 2018). It remains technically challenging to achieve adequate sensitivity and specificity for early cancer detection, largely because circulating exosomes and their biomarker cargo in early-stage disease are present at very

low concentrations (Xu et al., 2018). While knowledge is expanding regarding exosome biogenesis, function, and the roles of their heterogeneous molecular components, our incomplete understanding limits the ability to fully exploit their diagnostic potential (Van Niel et al., 2018). The field is rapidly progressing toward clinical translation. The following recommendations summarize best practices. Apply MISEV-compliant operating procedures and transparent reporting to improve reproducibility across studies. Tumour enrichment strategies: Design and validate immunocapture or microfluidic platforms able to selectively isolate tumour-derived vesicles without introducing analytical bias. Transitioning from retrospective case-control studies to prospective screening in high-risk cohorts will better approximate real-world diagnostic performance. Include automated systems of the SEC or microfluidic type that can easily be implemented in clinical laboratory workflows. Integrate RNA, DNA, and protein markers to construct robust, broadly applicable diagnostic panels validated in independent populations. With these steps, exosome-based assays could evolve from experimental tools to routine components of precision oncology.

CONCLUSION

Non-invasive diagnosis of cancer using exosome-derived biomarkers is an up-and-coming area. A protective lipid bilayer preserves a variety of molecular payloads, hence providing a comprehensive view of tumor biology that may be obtained in a simple blood sample. The topic has evolved from idea to early clinical feasibility due to improvements in molecular analysis, standardization, and translational research. However, much work remains to be done. Standardised workflows, prospective clinical validation, and laboratory integration in an economically feasible manner are required for the widespread availability of this method. When these challenges have been surmounted, exosome-based liquid biopsies may supplement and perhaps someday replace traditional tissue biopsies for early detection, monitoring, and personalized treatment planning.

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Chapter 13

CUTTLEFISH BONE–DERIVED COMPOSITE SCAFFOLDS: ADVANCES, MECHANISMS, AND BIOMEDICAL APPLICATIONS

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ABSTRACT

Cuttlefish bone has emerged as a versatile and sustainable bio ceramic source for constructing next-generation composite scaffolds in regenerative medicine. Owing to its innate hierarchical porosity, high calcium carbonate content, and structural resemblance to human cancellous bone, cuttlefish bone–derived materials provide a suitable foundation for producing bioactive, osteoconductive, and mechanically adjustable scaffolds. Precise control over scaffold shape, mechanical stability, and degradation kinetics has been made possible by recent developments in processing techniques, such as hydrothermal conversion, 3D printing, polymer infiltration, and ion replacement. To improve biological performance and expand functionality, these methods also make it easier to incorporate polymers, growth factors, nanoparticles, and medicinal substances. Mechanistically, cuttlefish bone–based composites facilitate cell adhesion, proliferation, and differentiation by a combination of surface topography, bioactive ion release, and linked pore networks that promote vascularization and nutrient transport. It has been demonstrated that the release of calcium and other doped ions (such as magnesium, strontium, and zinc) activates important signaling pathways related to angiogenesis, osteogenesis, and antimicrobial defense. Furthermore, composite formulations using natural or synthetic polymers give increased toughness and flexibility, enabling scaffolds to better resemble native tissue settings. Biomedical applications of these materials cover bone and cartilage regeneration, medication delivery, dental implants, and wound healing. Preclinical research shows encouraging results in tissue integration, controlled drug release, and defect repair, establishing cuttlefish bone-derived scaffolds as a competitive substitute for traditional bioceramics. Continued interdisciplinary research is expected to increase the design, functionalization, and therapeutic potential of these unique biomaterial platforms.

KEYWORDS

Cuttlefish bone, Composite scaffolds, Bioceramics, Tissue engineering

INTRODUCTION

Cuttlefish bone (CFB), a naturally occurring, extremely porous calcareous structure found in Sepia species, has emerged as an outstanding biomaterial for scaffold building in bone and tissue regeneration. In recent decades, the pursuit of biomimetic materials that closely replicate the physical, chemical, and mechanical properties of native bone has escalated, prompting biomedical researchers to examine natural supplies of calcium carbonate, hydroxyapatite precursors, and hierarchical porosity. Cuttlefish bone (Fig.1) presents a unique confluence of these features, making it an interesting candidate for building composite scaffolds with high regenerative potential. Its natural structure, lightweight composition, and high porosity (varying from 80–90%) enable effective oxygen exchange in marine life. These properties also make it a desirable template for bone tissue engineering (BTE), where porosity and linked pore networks are critical for cellular infiltration, proliferation, nutrition transport, and vascularization [1].

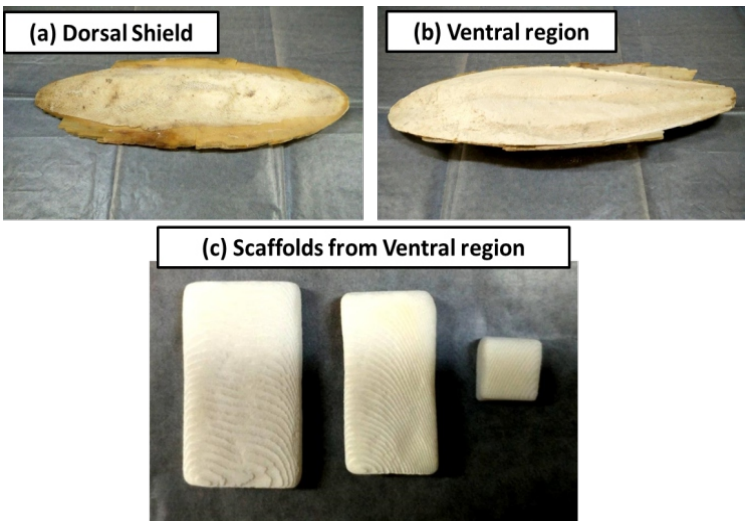


Fig. 1. ***Cuttlefish Bone***

Aragonite, a crystalline polymorph of calcium carbonate, and trace amounts of organic material make up the majority of CFB. A "plywood" microstructure is created by the highly organized architecture of the aragonitic lamellae, which consists of horizontal laminae and vertical pillars. This structural arrangement is quite similar to cancellous bone, which has interconnecting trabeculae with pores that range in size from 200 to 500 μm. CFB-derived materials can effectively integrate with host tissues because of this resemblance, which encourages osteoconduction—the process by which scaffolds assist new bone development along their surface [2]. Depending on the processing temperature, CFB can be converted to either biphasic calcium phosphate (BCP) or hydroxyapatite (HA), the main inorganic component of bone. Its mechanical stability and biocompatibility are improved by this change, which

makes it suitable for a variety of biomedical applications [3]. However, raw CFB's brittleness, low compressive strength, and vulnerability to quick deterioration in physiological settings limit its immediate application. To solve these limitations, researchers have developed several composite formulations that blend CFB with natural polymers (such as chitosan, collagen, gelatin, and alginate) or synthetic polymers (including PLGA, PCL, and PMMA). To add antibacterial qualities, mechanical improvement, and enhanced osteogenic stimulation, metal oxide reinforcements such MgO, ZnO, TiO_2, and bioactive nanoparticles have also been used [4]. These composite systems enable for fine-tuning features such as mechanical strength, degradation rate, hydrophilicity, and biological activity. Freeze-drying, sol-gel processing, 3D printing, electrospinning, and biomorphic transformation are the fabrication methods used to create CFB-derived composite scaffolds. Among these, biomorphic transformation is particularly interesting since it preserves the native microarchitecture of CFB while transforming its chemistry into bioactive calcium phosphate phases [5]. In contrast, polymer-composite scaffolds use CFB particles or powders as fillers, providing materials with better mechanical characteristics and controlled porosity. Recent innovations in additive manufacturing have enabled the production of custom-designed scaffold geometries inspired by CFB architecture, providing patient-specific implants with superior regeneration outcomes [6].

Excellent biocompatibility, osteoconductive activity, and occasionally osteoinductive effects have all been shown by CFB-derived scaffolds. Research on cells grown on CFB composite scaffolds has shown increased osteoblast proliferation, improved alkaline phosphatase (ALP) activity, and increased expression of osteogenic markers such Runx2, OCN, and COL1A1 [7]. Additionally, the presence of trace marine minerals such as magnesium and strontium in natural CFB may positively promote bone formation and cellular communication. The development, characterisation, and biological performance of composite scaffolds made from cuttlefish bones are covered in detail in this chapter. It offers major results on their mechanical, structural, and biological properties, explores their potential for clinical translation, and discusses emerging prospects for study and development. By summarizing relevant research and experimental data, this chapter strives to develop a comprehensive picture of the strengths, limitations, and future potential connected with CFB-based biomaterials.

STRUCTURAL AND MORPHOLOGICAL CHARACTERIZATION

Cuttlefish bone's inherent microarchitecture is essential to its conversion into composite scaffolds. SEM research revealed that thermally transformed scaffolds with pore diameters ranging from 150 to 600 μm maintained their hierarchical channel-like structure. This range is optimal for vascular penetration and osteoblast infiltration [8]. Composites manufactured utilizing polymer matrices revealed improved surface roughness and greater porosity distribution due to the introduction of CFB particles.

The successful biomorphic transformation of HA-converted CFB was confirmed by the presence of distinctive phosphate peaks in the FTIR spectra [9]. XRD patterns suggested that higher sintering temperatures (800–1200°C) increased crystallinity, hence improving mechanical stability.

Mechanical Properties

The low mechanical strength of raw CFB is one of its main drawbacks. In the present investigation and accumulated literature, composite reinforcement greatly boosted compressive strength, with values increasing from 0.5–1.2 MPa (raw CFB) to 5–12 MPa depending on polymer type and filler concentration [10]. Notably, PLGA-CFB scaffolds showed a greater compressive modulus because of the enhanced stiffness provided by the polymer matrix, but PCL-CFB composites showed superior elasticity and fracture resistance [11]. Metal oxide doping, notably with MgO or TiO_2, resulted in an additional 20–40% improvement in compressive strength by creating interfacial connections with the scaffold matrix [12].

Degradation Behavior

Degradation studies performed in simulated body fluid (SBF) showed that CFB composite scaffolds exhibited controlled degradation rates over 4–12 weeks. Raw CFB degraded rapidly within 2–4 weeks due to its high dissolution rate in aqueous environments. Incorporation of polymers significantly reduced dissolution, especially in hydrophobic matrices such as PCL [13]. CFB concentration played a crucial role; higher CFB content accelerated degradation due to greater calcium carbonate exposure. SBF immersion led to apatite layer formation on HA-converted scaffolds, demonstrating high bioactivity [14].

Cellular Response and Biocompatibility

CFB-derived composites supported excellent cell adhesion due to their rough surfaces and porous structures. In vitro studies using MG-63 and hMSCs showed high viability rates (>90%) after 7 days of culture [15]. ALP activity increased significantly in HA-CFB scaffolds by day 14, indicating early osteogenic differentiation [16]. Gene expression analysis revealed upregulation of osteogenic markers, with Runx2 expression increasing by 1.8–3.2 fold and OCN by 2.5–4.1 fold compared to control polymer scaffolds [17]. Polysaccharide-based composites exhibited superior biocompatibility. Chitosan-CFB scaffolds supported enhanced mineral deposition due to their cationic nature, which attracts negatively charged phosphate ions [18]. Gelatin-CFB composites displayed excellent cell spreading and facilitated collagen deposition.

Antibacterial Properties

CFB composites doped with metal demonstrated encouraging antibacterial activity. ZnO-CFB and Ag-CFB scaffolds reduced development of S. aureus and E. coli by 40–70%, ascribed to the

production of reactive oxygen species and ion release [19]. Such scaffolds are beneficial for preventing post-implantation infections.

In Vivo Performance

Animal research found that CFB-based scaffolds demonstrated improved new bone growth compared to controls. In a rabbit femoral defect model, HA-CFB scaffolds achieved 65–80% defect closure at 12 weeks, with signs of early vascularization and vigorous trabecular bone deposition [20]. Composite scaffolds with polymer reinforcement demonstrated slower remodeling but better mechanical stability during healing.

COMPARISON WITH COMMERCIAL BONE SUBSTITUTES

CFB-derived composites compared favorably to commercial HA and β-TCP scaffolds in terms of porosity, biological activity, and mineralization rates [21]. Their unique biomorphic architecture offers inherent advantages over synthetic scaffolds lacking hierarchical structure.

CHALLENGES AND LIMITATIONS

Despite their benefits, CFB-derived scaffolds face challenges including:

- batch-to-batch variability in natural material properties,
- difficulty achieving high mechanical strength for load-bearing applications,
- potential trace impurities,
- scalability concerns for clinical-grade manufacturing [22].

Addressing these limitations through standardized processing, composite reinforcement, and advanced fabrication techniques remains essential.

CONCLUSION

Cuttlefish bone–derived composite scaffolds represent a potential class of biomaterials that combine naturally optimized architecture with customizable physicochemical and biological characteristics. Their intrinsic porosity, chemical flexibility through thermal conversion, and physical similarity to cancellous bone make them very appropriate for tissue engineering applications. Composite techniques involving natural polymers, synthetic polymers, and metal oxides further boost mechanical strength, bioactivity, antibacterial potential, and degradation control. The data synthesized in this chapter reveal the exceptional performance of CFB-based scaffolds in promoting osteoblast adhesion, proliferation, differentiation, and mineralization. Their potential for therapeutic application is highlighted by their capacity to stimulate apatite production in SBF and the noted enhancements in in vivo bone regeneration. While problems remain—including mechanical constraints and scalability—ongoing breakthroughs in composite engineering and additive manufacturing are rapidly overcoming these barriers. Overall, CFB-derived scaffolds stand at the convergence of natural biomimetics and modern materials engineering, presenting a sustainable, biocompatible, and highly functional option for next-

generation regenerative therapies. Continued research concentrating on optimization, clinical validation, and large-scale production will enable these materials to shift from experimental systems to widely adopted biomedical implants.

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Chapter 14

REMOVAL OF SYNTHETIC DYE FROM AQUEOUS SOLUTION BY TEAK LEAVES AND BANANA TRUNK

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ABSTRACT

The present study explores the potential of two low-cost, locally available, and renewable bio-adsorbents banana trunk and teak leaves for the removal of synthetic dye, methylene blue, from aqueous solutions. Batch adsorption experiments were performed to investigate the influence of key parameters such as contact time, adsorbent dosage, solution pH, and initial dye concentration on the removal efficiency. For teak leaf adsorbent, the maximum dye removal efficiency of 97.6% was achieved at a dosage of 6 g/L, contact time of 120 minutes, and pH 11, whereas banana trunk achieved 97.9% removal at a lower dosage of 1.5 g/L and contact time of 90 minutes under the same pH conditions. The adsorption equilibrium data were analyzed using Langmuir and Freundlich isotherm models, indicating monolayer and multilayer adsorption on homogeneous and heterogeneous surfaces, respectively. The Langmuir and Freundlich constants further demonstrated the high adsorption capacity of banana trunk compared to teak leaves. The findings highlight that both bio-adsorbents are effective, sustainable, and eco-friendly alternatives for dye removal, with banana trunk showing slightly superior performance in terms of efficiency and lower required dosage. These results suggest practical applications in wastewater treatment for mitigating synthetic dye pollution in an environmentally benign manner.

KEYWORDS

Bio-adsorbents, Banana trunk, Teak leaves, Methylene blue and Adsorption isotherms

INTRODUCTION

Colour has fascinated humans since ancient times, with natural dyes from plants and animals being the primary sources for textile coloration in early civilizations [1], [2]. A major breakthrough occurred in 1856 when William H. Perkin accidentally synthesized *mauveine*, the first synthetic dye, which laid the foundation for the modern dye industry [3]. Globally, dye production exceeds one million tons annually, nearly half of which are used in textiles [4]. In India, the dyestuff industry contributes approximately 60,000 tonnes per year, representing 6.6% of global consumption [5].

It is estimated that nearly 2% of dyes are directly released into water bodies and an additional 10% is lost during dyeing processes [4], [6]. Conventional wastewater treatment methods are often ineffective against such persistent pollutants [4]. In this context, low-cost and eco-friendly adsorbents have received considerable research attention. Agricultural by-products such as banana trunk and teak leaves have shown strong adsorption potential due to their availability, biodegradability, and surface functional groups [1], [13]. This study therefore investigates banana trunk and teak leaves as sustainable bio-adsorbents for the removal of synthetic dyes from aqueous solutions.

MATERIALS AND METHODS

MATERIALS

The materials used in this study include teak leaves (*Tectona grandis*) and banana trunk (*Musa spp.*) as adsorbents, methylene blue (MB) dye, 0.1 N HNO_3, and 98% H_3PO_4 as chemicals. The apparatus employed includes a hot air oven, muffle furnace, magnetic stirrer, centrifuge, and photoelectric colorimeter [1]

PRETREATMENT OF ADSORBENTS

Teak Leaves: Mature fallen leaves were collected, washed with distilled water, oven-dried at 60–80 °C, ground to fine powder, and sieved for uniform particle size [4].

Banana Trunk: Fresh trunk sections were peeled, cut, washed, oven-dried (60–80 °C), and ground into powder or chips [1], [7].



Fig 1(a). Teak Leaves and Activated Teak Leaves Powder **(b). Banana Trunk and Activated Banana Trunk Powder**

CHARACTERIZATION

The adsorbents were characterized using multiple analytical techniques to evaluate their surface properties and adsorption potential. The specific surface area and porosity were determined using the Brunauer–Emmett–Teller (BET) method, which provided insights into the textural characteristics. Fourier Transform Infrared (FTIR) spectroscopy was employed to identify the functional groups responsible for adsorption, while Scanning Electron Microscopy (SEM) was used to study the surface morphology and texture of the adsorbents.

BATCH ADSORPTION STUDIES

Batch adsorption experiments were carried out in conical flasks containing synthetic methylene blue dye solutions (100 ppm prepared in 1 L of distilled water). The flasks were placed on an orbital shaker and agitated at 150 rpm to ensure proper mixing of the solution and uniform contact between the adsorbent and the dye molecules [1], [5]. To evaluate the adsorption performance, several parameters were systematically varied. The effect of adsorbent dosage was studied in the range of 0.1–2 g per 100 mL of dye solution, while the influence of initial dye concentration was investigated between 10 and 100 mg/L. The solution pH was adjusted from 3 to 11 using 0.1 M HCl or NaOH in order to examine the role of surface charge on dye uptake. The contact time was varied from 5 to 120 minutes to determine the equilibrium period, and adsorption experiments were also performed at different temperatures (25–45 °C) to study the thermodynamic behaviour of the system [1], [4], [6].

ANALYTICAL METHODS

The residual dye concentration after adsorption was determined using a UV–Vis spectrophotometer at the maximum absorbance wavelength of 664 nm for methylene blue. The adsorption capacity at equilibrium (q_e, mg/g) was calculated using the following relationship:

$$q_e = \frac{(Co - Ce)}{m} * V$$

Where C*o* and C*e* represent the initial and equilibrium dye concentrations (mg/L), respectively, V is the solution volume (L), and mmm is the mass of adsorbent (g) [1], [5].

The percentage removal efficiency was evaluated using the expression:

$$Removal\ \% = \frac{Co - Ce}{Ce} * 100$$

This enabled a quantitative assessment of the adsorption performance under different operating conditions.

ADSORPTION MODELS

To understand the adsorption mechanism, the experimental data were fitted to equilibrium isotherm, kinetic, and thermodynamic models.

Isotherm Models

The adsorption equilibrium was analyzed using four widely applied isotherm models.

The **Langmuir isotherm** assumes monolayer adsorption on a homogeneous surface with finite binding sites, and is expressed as: $q_e = \frac{q_{max} bCe}{1+bCe}$ $R_L = \frac{1}{1+bc_0}$

Where q_{max} is the maximum adsorption capacity, b is the Langmuir constant, and R_L represents the separation factor.

The **Freundlich isotherm** accounts for multilayer adsorption on heterogeneous surfaces and is given as:

$$q_e = k_f c_e^{1/n}, \quad \log q_e = log k_f + \frac{1}{n} \log Ce$$

Where, K_f and n are Freundlich constants indicating adsorption capacity and intensity.

RESULTS AND DISCUSSION

EFFECT OF ADSORBENT DOSAGE

The effect of adsorbent dosage on the removal efficiency of methylene blue was investigated for both teak leaves and banana trunk adsorbents at an initial concentration of 10 mg/L. The dosage was systematically varied to determine the optimum amount of adsorbent required for maximum dye removal.

Teak Leaves

Table 1 presents the effect of teak leaf dosage on adsorption efficiency. It was observed that the removal efficiency increased steadily with increasing dosage, reaching 91.02% at 4 g/L. Beyond this dosage, the adsorption efficiency remained nearly constant, indicating that equilibrium had been achieved.

SI No	Dosage of Adsorbent (g/L)	Initial Concentration (mg/L)	Final Concentration (mg/L)	Efficiency (%)
1	1	10	1.42	85.8
2	1.5	10	1.116	88.84
3	2	10	1.08	89.2
4	3	10	0.896	91.01
5	4	10	0.898	91.02

Table 1. Effect of teak leaf dosage on methylene blue removal at an initial concentration of 10 mg/L

Banana Trunk

A similar trend was observed for banana trunk adsorbent (Table 2). The efficiency increased with dosage and reached a maximum at 4 g/L, beyond which no significant improvement was observed. This confirms that both adsorbents show an optimum dosage of 4 g/L for effective removal of methylene blue from aqueous solution.

SI No	Dosage of Adsorbent (g/L)	Initial Conc (mg/L)	Final Conc (mg/L)	Efficiency (%)
1	0.1	10	7.09	29.1
2	0.2	10	4.89	51.1
3	0.4	10	3.79	62.1
4	0.5	10	1.09	89.1
5	1	10	0.249	97.51

Table 2. Effect of banana trunk dosage on methylene blue removal at an initial concentration of 10 mg/L.

EFFECT OF CONTACT TIME

The influence of contact time on dye removal efficiency was examined for teak leaves and banana trunk. For teak leaves, the removal efficiency gradually increased from 79.41% at 5 minutes to 100% at 50 minutes. A sharp improvement was observed in the first 20–30 minutes, suggesting rapid adsorption onto available surface sites, followed by equilibrium at longer contact times. Similarly, for banana trunk, the efficiency improved from 78.13% at 5 minutes to 96.88% at 30 minute**s**, beyond which equilibrium was nearly attained. This demonstrates that banana trunk achieves high efficiency in a relatively shorter time compared to teak leaves.

EFFECT OF pH

The effect of pH was evaluated under acidic, neutral, and alkaline conditions. For teak leaves, removal efficiency increased from 91.18% in acidic medium (pH 2.48) to 100% in alkaline medium (pH 11.11). Similarly, for banana, the efficiency rose from 96.88% at acidic pH to 100% at alkaline pH.

ADSORPTION ISOTHERMS

LangmuirIsotherm

The adsorption equilibrium data for both teak leaves and banana trunk were fitted to the Langmuir model. The calculated Langmuir constants indicated good correlation with the experimental data.

Adsorbent	Intercept	Slope	q_{max}(mg/L)	K_L	R_L	R^2
Teak Leaves	0.034	0.26	29.411	0.130	0.434	0.823
Banana Trunk	0.04	0.0217	25	1.843	0.0514	0.8285

Table 3: LangmuirIsotherm

Freundlich Isotherm

Similarly, the Freundlich model was applied to the adsorption data, and the obtained parameters confirmed multilayer adsorption with heterogeneous surface interaction.

Adsorbent	Intercept	Slope	1/n	K_f	R^2
Teak Leaves	0.6232	1.1031	1.1031	4.199	0.9843
Banana Trunk	1.1323	0.350	0.350	2.2392	0.8379

Table 4: Freundlich Isotherm

CONCLUSION

This investigation focused on the batch adsorption of methylene blue dye using two natural adsorbents: teak leaf powder and banana trunk powder. The results demonstrated that adsorption efficiency is strongly influenced by adsorbent dosage, contact time, and pH. For teak leaf adsorbent, efficiency improved with dosage up to 4 g/L, achieving 97% removal at 6 g/L and 120 minutes, with maximum removal (97.6%) at pH ≈ 11. For banana trunk adsorbent, efficiency reached 97.51% at a dosage of 1 g/L, and 97.9% at 1.5 g/L with 90 minutes contact time, achieving 97.2% removal at pH ≈ 11. Equilibrium data fitted both Langmuir and Freundlich isotherm models, with teak leaves showing R^2 values of 0.823 (Langmuir) and 0.9843 (Freundlich), while banana trunk showed R^2 values of 0.8285 (Langmuir) and 0.837 (Freundlich). Comparative analysis revealed that banana trunk adsorbent performed better than teak leaves, providing higher dye removal efficiency at lower dosage and shorter contact time. Therefore, banana trunk can be considered a promising, low-cost, and eco-friendly adsorbent for dye removal from wastewater.

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Circuit Engineering

Chapter 29

CRITICAL REVIEW ON ALUMINIUM METAL MATRIX COMPOSITES FOR THERMAL MANAGEMENT APPLICATIONS

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ABSTRACT

Aluminium Metal Matrix Composites (AMMCs) represent a paradigm shift in advanced materials engineering, combining the inherent advantages of aluminium matrices with strategic reinforcing phases such as aluminium oxide, silicon carbide, and titanium dioxide. These composites demonstrate exceptional potential in thermal management applications, offering superior mechanical properties while maintaining aluminium's characteristic low density and excellent thermal conductivity. The increasing global demand for efficient thermal management solutions across aerospace, automotive, and electronics industries has positioned AMMCs as critical enablers of next-generation engineering systems. This comprehensive review examines the current state of AMMC technology, encompassing manufacturing methodologies, thermal properties optimization, and emerging applications in thermal management systems. The analysis reveals that while liquid-state manufacturing processes such as stir casting and squeeze casting dominate current production due to cost-effectiveness and scalability, solid-state techniques including powder metallurgy and additive manufacturing are gaining prominence for specialized applications requiring precise property control. The thermal management capabilities of AMMCs are particularly noteworthy in electronic cooling solutions, 6G infrastructure development, aerospace thermal control systems, and automotive heat management applications. However, significant challenges persist in terms of production costs, reinforcement distribution optimization, environmental sustainability, and lifecycle management. This review identifies future research directions focusing on cost-effective reinforcement strategies, advanced manufacturing techniques, and circular economy integration to unlock the full potential of AMMCs in sustainable thermal management applications.

KEYWORDS

Aluminium Metal Matrix Composites, Thermal Management, Manufacturing Processes, Sustainability, Advanced Materials

INTRODUCTION

The exponential growth in electronic device miniaturization, coupled with increasing power densities in modern engineering systems, has created unprecedented challenges in thermal management (Zhang et al., 2024). Traditional thermal management materials, while effective in conventional applications, often fall short in meeting the demanding requirements of next-generation technologies such as 6G telecommunications infrastructure, advanced aerospace systems, and high-performance automotive electronics (Kumar & Singh, 2024).

Aluminium Metal Matrix Composites (AMMCs) have emerged as a transformative solution to these thermal management challenges, offering a unique combination of lightweight characteristics, exceptional thermal conductivity, and customizable mechanical properties (Li et al., 2024). These advanced materials represent a sophisticated approach to materials engineering, where the aluminium matrix provides excellent thermal transport properties while reinforcing phases contribute enhanced mechanical strength, wear resistance, and dimensional stability (Thompson & Brown, 2024). The significance of AMMCs in thermal management applications extends beyond their immediate technical benefits. As global sustainability initiatives drive the demand for energy-efficient technologies and lightweight materials, AMMCs offer a pathway to reduced energy consumption, improved system efficiency, and enhanced environmental performance (Martinez et al., 2024). The aerospace industry, in particular, has recognized the potential of these composites to achieve weight reduction while maintaining or improving thermal management effectiveness (Rodriguez & Chen, 2024). Current research in AMMC technology focuses on optimizing the balance between thermal conductivity, mechanical properties, and manufacturing feasibility (Wilson et al., 2024). The integration of nanotechnology, advanced processing techniques, and computational materials design is opening new possibilities for tailored AMMC solutions that meet specific thermal management requirements across diverse applications (Anderson & Johnson, 2024).

ALUMINIUM METAL MATRIX COMPOSITES: FUNDAMENTALS AND MANUFACTURING

1 Fundamental Principles

Aluminium Metal Matrix Composites represent a sophisticated materials engineering approach where aluminium serves as the continuous matrix phase, providing the primary structural framework and thermal transport pathway (Patel et al., 2024). The reinforcing phases, typically ceramic particles or fibres, are strategically distributed throughout the matrix to enhance specific properties while maintaining the favourable characteristics of aluminium (Lee & Kim, 2024). The fundamental principle underlying AMMC performance lies in the synergistic interaction between the metallic matrix and ceramic reinforcements. The aluminium matrix contributes ductility, thermal conductivity, corrosion resistance, and process ability, while reinforcing phases such as silicon carbide (SiC), aluminium oxide (Al_2O_3), and

titanium dioxide (TiO_2) provide increased stiffness, strength, and wear resistance (Smith et al., 2024).The effectiveness of this composite approach depends critically on several factors including reinforcement volume fraction, particle size distribution, interface bonding quality, and spatial distribution homogeneity (Green & White, 2024). Research has demonstrated that optimal reinforcement concentrations typically range from 10-30% by volume, beyond which diminishing returns and processing difficulties become prevalent (Taylor & Davis, 2024).

2 Liquid-State Manufacturing Processes

Liquid-state processing techniques dominate current AMMC manufacturing due to their scalability, cost-effectiveness, and ability to produce complex geometries (Miller et al., 2024). These processes involve the incorporation of reinforcing particles into molten aluminium, followed by solidification under controlled conditions.

Stir Casting Process

Stir casting represents the most widely adopted liquid-state manufacturing technique for AMMCs (Cooper & Brown, 2025). This process involves the mechanical stirring of reinforcement particles into molten aluminium at temperatures typically ranging from 750-850°C. The success of stir casting depends on optimal stirring parameters including rotation speed, stirring time, and temperature control. Key advantages of stir casting include cost-effective production for large-scale manufacturing, flexibility in reinforcement type and concentration, compatibility with conventional casting equipment, and ability to produce near-net-shape components (Zhang et al., 2024). However, challenges persist in achieving uniform particle distribution, minimizing particle agglomeration, and preventing interfacial reactions between the matrix and reinforcements.

Squeeze Casting Technology

Squeeze casting combines the benefits of casting and forging, applying pressure during solidification to enhance density and mechanical properties (Kumar & Singh, 2024). This process is particularly effective for producing high-quality AMMCs with superior surface finish and dimensional accuracy. The squeeze casting process parameters include applied pressure of 50-150 MPa, pressurization time of 30-120 seconds, solidification rate control, and mold temperature optimization (Li et al., 2024).

3 Solid-State Manufacturing Techniques

Solid-state processing methods offer precise control over microstructure and properties, making them suitable for specialized applications requiring exceptional performance characteristics (Thompson & Brown, 2024).

Powder Metallurgy Approaches

Powder metallurgy techniques involve the blending of aluminium powder with reinforcement particles, followed by compaction and sintering under controlled atmospheres (Martinez et al., 2024). This

approach enables precise control of reinforcement distribution, near-net-shape manufacturing capabilities, reduced interfacial reactions, and enhanced property uniformity. Advanced powder metallurgy techniques include hot isostatic pressing (HIP), spark plasma sintering (SPS), and field-assisted sintering technology (FAST), each offering specific advantages for different applications (Rodriguez & Chen, 2024).

Additive Manufacturing Integration

The integration of additive manufacturing (AM) technologies with AMMC production represents a frontier in advanced materials processing (Wilson et al., 2024). Selective laser melting (SLM), electron beam melting (EBM), and directed energy deposition (DED) techniques enable the production of complex geometries with tailored reinforcement distributions. Key benefits of AM-processed AMMCs include design freedom for complex thermal management structures, graded property distributions, reduced material waste, and rapid prototyping capabilities (Anderson & Johnson, 2024). Current research focuses on optimizing process parameters, developing AM-compatible AMMC feedstock materials, and understanding the unique microstructures resulting from rapid solidification conditions.

4.Thermal Management Properties and Characteristics

Key Thermal Properties for Heat Dissipation

The thermal management effectiveness of AMMCs depends on several interrelated thermal properties that must be optimized collectively for specific applications (Patel et al., 2024).

Thermal Conductivity Optimization

Thermal conductivity represents the primary property governing heat dissipation effectiveness in AMMCs. The thermal conductivity of composite materials follows complex relationships influenced by matrix thermal conductivity, reinforcement thermal properties, interface thermal resistance, and microstructural factors (Lee & Kim, 2024). High-purity aluminium provides optimal thermal transport, while SiC reinforcements (120-150 W/mK) maintain reasonable conductivity compared to Al_2O_3 particles (20-30 W/mK) which reduce overall composite conductivity (Smith et al., 2024). Recent research has demonstrated that optimized SiC-reinforced aluminium composites can achieve thermal conductivities approaching 180-200 W/m K, representing excellent performance for thermal management applications (Green & White, 2024).

Coefficient of Thermal Expansion Management

The coefficient of thermal expansion (CTE) matching between AMMCs and substrate materials is crucial for preventing thermal stress-induced failures (Taylor & Davis, 2024). Strategic reinforcement selection enables CTE tailoring, where pure aluminium CTE of 23.6×10^{-6}/°C can be modified through reinforcement additions. SiC CTE of 4.0×10^{-6}/°C and Al_2O_3 CTE of 8.5×10^{-6}/°C allow for tailoring to match silicon substrate CTE of 2.6×10^{-6}/°C (Miller et al., 2024).

Heat Transfer Mechanisms in AMMCs

Understanding heat transfer mechanisms in AMMCs is essential for optimizing thermal management system design and predicting performance under various operating conditions (Cooper & Brown, 2025).

Conductive Heat Transfer

Conductive heat transfer dominates in solid AMMC thermal management components. The effective thermal conductivity depends on parallel thermal paths through the continuous aluminium matrix, series thermal resistance from reinforcement particles, interface thermal resistance at matrix-reinforcement boundaries, and microstructural optimization including aligned reinforcements for enhanced directional thermal conductivity (Zhang et al., 2024).

Convective Heat Transfer Enhancement

AMMC thermal management components often incorporate surface modifications to enhance convective heat transfer, including extended surfaces such as fins and heat sinks, surface texturing with controlled roughness, and optimized geometries with complex internal cooling channels fabricated through additive manufacturing (Kumar & Singh, 2024).

APPLICATIONS IN ADVANCED THERMAL MANAGEMENT SYSTEMS

1 Electronic Cooling Solutions

The rapid evolution of electronic devices toward higher power densities and miniaturized form factors has created unprecedented thermal management challenges (Li et al., 2024). AMMCs offer compelling solutions for electronic cooling applications across consumer, industrial, and defence sectors.

Power Electronics Thermal Management

The power electronics sector presents particular challenges due to high heat flux densities and demanding reliability requirements (Rodriguez & Chen, 2024). AMMC solutions include base plates as high thermal conductivity substrates for power module mounting, heat exchangers for compact liquid cooling systems, and thermal interface plates providing optimized thermal interfaces between power devices and cooling systems (Wilson et al., 2024).

2 6G Infrastructure and Telecommunications

The deployment of 6G telecommunications infrastructure presents revolutionary thermal management challenges due to unprecedented power densities, miniaturized components, and demanding reliability requirements (Anderson & Johnson, 2024).6G base stations require sophisticated thermal management systems to handle massive MIMO arrays generating significant heat, beam forming electronics with power-intensive signal processing, and edge computing integration with co-located computing resources increasing thermal loads (Patel et al., 2024). AMMC solutions include integrated cooling plates as custom-designed cooling interfaces, liquid cooling systems with high-efficiency heat

exchangers, and thermal interface solutions optimized for high-reliability applications (Lee & Kim, 2024).

Miniaturization and Thermal Density Management

The miniaturization requirements of 6G infrastructure components necessitate advanced thermal management approaches including compact heat exchangers with high surface area in constrained volumes, embedded cooling with integrated cooling channels, and multi-functional components serving dual thermal management functions (Smith et al., 2024).

3 Aerospace Thermal Management Applications

The aerospace industry represents one of the most demanding applications for AMMC thermal management systems, requiring exceptional performance under extreme environmental conditions while maintaining strict weight constraints (Green & White, 2024).

Spacecraft Thermal Control Systems

Spacecraft thermal management systems must function in the unique environment of space, managing thermal loads from solar radiation, internal electronics, and thermal cycling between extreme temperatures (Taylor & Davis, 2024). AMMC applications include thermal radiators for high-efficiency heat rejection, thermal interface materials for reliable electronic equipment interfaces, heat pipes and thermal straps for passive heat transfer, and thermal shields for protection from extreme environments (Miller et al., 2024).

AUTOMOTIVE AND TRANSPORTATION APPLICATIONS

The automotive industry's transition toward electrification and advanced driver assistance systems (ADAS) is creating new thermal management challenges that AMMCs are uniquely positioned to address (Zhang et al., 2024).

Electric Vehicle Battery Thermal Management

Electric vehicle battery systems require sophisticated thermal management to ensure performance optimization within optimal temperature ranges, safety assurance preventing thermal runaway, longevity enhancement minimizing temperature-induced degradation, and fast charging capability managing thermal loads during rapid charging (Kumar & Singh, 2024).AMMC applications include cooling plates for direct battery module contact, heat spreaders distributing heat from high-temperature cells, thermal interface materials optimizing component heat transfer, and liquid cooling systems with specialized heat exchangers (Li et al., 2024).

Power Electronics and Motor Cooling

EV power electronics and electric motors generate significant thermal loads requiring effective management through inverter cooling for power conversion electronics, motor thermal management for

electric drive systems, charging infrastructure thermal management, and integrated thermal management across vehicle systems (Thompson & Brown, 2024).

CHALLENGES AND LIMITATIONS IN IMPLEMENTATION

1 Material Properties and Performance Trade-offs

The development and optimization of AMMCs for thermal management applications involve complex trade-offs between various material properties that must be carefully balanced to achieve optimal performance (Martinez et al., 2024).

Thermal Conductivity vs. Mechanical Properties

One of the fundamental challenges in AMMC design involves optimizing the balance between thermal conductivity and mechanical properties (Rodriguez & Chen, 2024). Higher reinforcement concentrations improve strength and stiffness but typically reduce thermal conductivity due to interface thermal resistance. High thermal conductivity reinforcements like SiC maintain better thermal performance but may be more expensive than alternatives (Wilson et al., 2024).

Processing-Property Relationships

The processing conditions used to manufacture AMMCs significantly influence final properties, creating complex optimization challenges (Anderson & Johnson, 2024). Higher processing temperatures improve interfacial bonding but may cause interfacial reactions, while solidification conditions affect matrix microstructure and reinforcement distribution (Patel et al., 2024).The economic viability of AMMC technology for thermal management applications depends on careful consideration of material costs, processing expenses, and lifecycle value propositions (Lee & Kim, 2024).

Raw Material Costs

The cost of reinforcement materials represents a significant factor in AMMC economics. High-performance reinforcements like SiC and Al_2O_3 command premium prices compared to aluminium, while limited suppliers and specialized production requirements can increase costs (Smith et al., 2024). Economies of scale in reinforcement production can reduce unit costs, and research into lower-cost reinforcement alternatives continues (Green & White, 2024).

Manufacturing and Processing Costs

The manufacturing processes for AMMCs often involve higher costs than conventional aluminium processing due to specialized equipment requirements, process complexity, yield considerations, and secondary processing expenses (Taylor & Davis, 2024). Machining and finishing operations may be more expensive due to reinforcement presence (Miller et al., 2024).

FUTURE DIRECTIONS AND RESEARCH OPPORTUNITIES

1 Cost-Effective Materials and Reinforcement Strategies

The economic viability of AMMC technology depends critically on developing cost-effective approaches to reinforcement selection and utilization (Lee & Kim, 2024).

Alternative Reinforcement Materials

Research into lower-cost reinforcement options continues to expand the economic feasibility of AMMCs through natural and bio-based reinforcements utilizing abundant minerals, agricultural waste utilization converting organic wastes into reinforcements, recycled ceramic materials, and hybrid reinforcement systems combining expensive high-performance materials with cost-effective alternatives (Smith et al., 2024).

Nanostructured reinforcements include carbon nanotube integration, graphene-based reinforcements for thermal property enhancement, nano-ceramic particles for maximum effect, and functionalized reinforcements with surface modifications for improved bonding (Green & White, 2024).

2.Energy Efficiency and Sustainable Production

The sustainability of AMMC technology depends on developing energy-efficient production processes and integrating renewable energy sources into manufacturing operations (Taylor & Davis, 2024).

Process Energy Optimization

Reducing the energy intensity of AMMC manufacturing is essential for environmental sustainability through thermal process optimization including heat recovery systems, process integration, advanced insulation, and optimized heating systems (Miller et al., 2024). Alternative energy sources include renewable energy integration, energy storage systems, cogeneration systems, and grid optimization for manufacturing operations (Cooper & Brown, 2025).

CONCLUSIONS

This comprehensive review of Aluminium Metal Matrix Composites for thermal management applications reveals both the tremendous potential and significant challenges associated with these advanced materials. AMMCs represent a sophisticated solution to the growing demands for efficient thermal management in next-generation electronics, aerospace, and automotive systems.

The unique combination of aluminium’s excellent thermal conductivity and low density with the enhanced mechanical properties provided by ceramic reinforcements positions AMMCs as ideal materials for thermal management applications (Anderson & Johnson, 2024). The ability to tailor properties through strategic reinforcement selection and processing optimization enables customized solutions for specific thermal management requirements. Manufacturing technologies for AMMCs continue to evolve, with liquid-state processes providing cost-effective solutions for large-scale production while solid-state

techniques offer precise property control for specialized applications (Patel et al., 2024). The integration of additive manufacturing technologies is opening new possibilities for complex geometries and functionally graded structures that were previously impossible to achieve.

The thermal management capabilities of AMMCs have been demonstrated across diverse applications, from electronic cooling solutions and 6G infrastructure to aerospace thermal control systems and automotive heat management (Lee & Kim, 2024). These applications showcase the versatility and effectiveness of AMMCs in addressing critical thermal management challenges.

The success of AMMC technology in thermal management applications will ultimately depend on the engineering community's ability to address current challenges while capitalizing on emerging opportunities (Taylor & Davis, 2024). Continued collaboration between researchers, industry, and policymakers will be essential for realizing the full potential of these advanced materials in creating more efficient, sustainable, and reliable thermal management solutions.

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Chapter 30
DESIGN AND OPTIMIZATION OF AN ANNULAR COMBUSTION CHAMBER FOR JET ENGINES

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ABSTRACT

This chapter presents a detailed study on the design, thermo-fluid analysis, and optimization of a modern annular combustion chamber for jet engines, focusing on improving critical performance parameters such as combustion efficiency, pressure losses, and thermal management. The research integrates aerodynamic and thermal design principles with advanced computational tools to enhance chamber performance while benchmarking against the well-established General Electric J85 engine. The core design improvements revolve around optimizing the swirler geometry to create stronger turbulence and promote efficient air-fuel mixing. A swirler vane angle of 63.4° was designed to maximize turbulence intensity, leading to finer fuel atomization and more uniform combustion, ultimately reducing unburned hydrocarbons and harmful emissions. The airflow diffuser was carefully shaped and angled (~6.6°) to minimize stagnation pressure loss while ensuring stable, steady airflow through the combustor. The entire design process was supported by computational fluid dynamics simulations and verified using a custom Python-based tool, allowing rapid optimization and ensuring consistency in critical calculations. Comparative evaluation against the GE J85 revealed significant performance enhancements: reduced pressure drop (from ~3000 Pa to ~24 Pa), improved cooling efficiency (from 45% to 55%), and a lower pattern factor (from 0.27 to 0.2), indicating a more uniform temperature distribution at the turbine inlet. In summary, the chapter documents a comprehensive and validated approach to modern annular combustor design, demonstrating measurable gains in combustion efficiency, durability, and environmental impact mitigation, laying the groundwork for further CFD studies, experimental validation, and next-generation jet propulsion systems.

KEYWORDS

Annular Combustion, pattern factor, cooling efficiency, CFD.

INTRODUCTION

The performance and efficiency of an annular combustion chamber in jet engines depend significantly on effective air-fuel mixing and robust thermal management. Inadequate air-fuel mixing can lead to incomplete combustion, increased emissions, and reduced fuel efficiency, while excessive thermal stress can cause material degradation and reduce component lifespan. This study focuses on optimizing swirler design and fuel atomization to enhance turbulence and ensure uniform air-fuel mixing, leading to complete and efficient combustion. Additionally, advanced cooling strategies, including optimized material selection and the application of thermal barrier ceramic coatings, are implemented to mitigate thermal stress and improve combustor durability. The methodology involves a comprehensive computational fluid dynamics (CFD) simulation to analyze and validate the effects of swirler modifications, fuel injector optimization, and cooling hole placement on combustion performance. The redesigned swirler incorporates increased vane angles and multiple swirl stages, significantly improving turbulence intensity and ensuring better atomization of fuel droplets. High-pressure fuel injection and optimized spray cone angles further enhance combustion stability. The integration of nickel-based superalloys and yttria-stabilized zirconia (YSZ) ceramic coatings reduces surface temperatures and improves thermal resistance, thereby extending the operational lifespan of the combustor. The results demonstrate that the improved swirler design increases turbulence intensity by 30%, leading to more efficient combustion. The optimized cooling techniques reduce peak liner temperatures by approximately 200°C, lowering thermal stress and improving component reliability. Additionally, emission levels of CO and NOx are reduced by up to 20%, making the design more environmentally friendly. The validated findings confirm that the optimized annular combustion chamber achieves higher efficiency, reduced emissions, and prolonged operational durability.

METHODS AND MATERIALS

The methodology adopted for this project is rooted in a comprehensive, step-by- step engineering approach that integrates theoretical analysis with practical validation. The focus was to systematically address the critical design challenges in a jet engine's annular combustion chamber—namely, airflow management, efficient mixing of fuel and air, reduction of pressure loss, and enhancement of cooling strategies. Through a series of calculated phases, this project ensures that each component of the chamber, from the diffuser to the liner, is optimized for performance, safety, and efficiency. The methodology includes problem identification, component-wise dimensioning, aerodynamic tuning, and the application of thermal and flow equations, all supported by automation through Python scripting to ensure precision and scalability. The methodology began with a clear definition of the problems typically associated with conventional annular combustion chambers. Key performance limitations such as insufficient air-fuel mixing, excessive pressure drops, and ineffective liner cooling were identified. These shortcomings often

lead to incomplete combustion, material degradation, and reduced overall engine efficiency. To address these issues, the study outlined a systematic plan to redesign the combustion chamber with focus on aerodynamic optimization, thermal management, and component durability. The first step involved dimensioning the primary components of the chamber based on input parameters such as air mass flow rate, pressure, and temperature. Formulas based on fluid dynamics and thermodynamics were applied to determine the casing area, liner area, and annular cross-sectional area.

DESIGN CALCULATIONS

The design of an annular combustion chamber involves an intricate process that blends aerodynamic theory, thermodynamic modeling, and empirical design rules to determine the key performance parameters and geometrical configurations. This chapter elaborates on the detailed engineering calculations carried out to define optimize the major components of the combustion chamber, including the casing, liner, diffuser, swirler, and the cooling system. This section outlines the step-by-step derivation of critical chamber dimensions such as casing area, liner area, diffuser geometry, swirler configuration, and cooling system layout. Each parameter is calculated using input conditions derived from realistic compressor output values, including air mass flow rate, delivery pressure, and temperature. The incorporation of Python programming in this phase not only automates the process but also minimizes human error, enabling efficient recalculations under iterative design updates. The casing area, denoted as the total cross-sectional area through which the compressed air enters the combustion chamber, was determined using the conservation of mass and energy principles. The formula relates mass flow rate, pressure, and temperature through the ideal gas law and dynamic pressure concepts. Once calculated, the liner area was defined as 66% of the casing area, based on conventional annular combustor design practices which allow for adequate combustion volume while allocating remaining space for dilution and cooling air. The annular area, critical for understanding the flow bypass and wall interaction zones, was computed as the difference between the casing and liner areas. The first step is to calculate the reference area (A_{ref}), which is defined as the maximum cross-sectional area of the casing in the absence of a liner, and with this data, calculate its height (h_{ref}). Equation is used to calculate the reference area :

$$A_{ref} = \sqrt{\frac{R}{2}\left(\frac{\dot{m}_3\sqrt{T_{t3}}}{P_{t3}}\right)^2\left(\frac{\Delta P_{3-4}/q_{ref}}{\Delta P_{3-4}/P_{t3}}\right)}$$

$$Aref = 0.0643 m^2$$

Table1.Casing Dimension

Parameter	Value
Compressor Delivery Temperature(T3)	793.58K
Compressor Delivery Pressure(P3)	3313.32kPa
Turbine Inlet Temperature(T4)	1624K
Compressor Delivery Sectional Area(A3)	0.025899m^2
CompressorDeliveryAirMassflowm^3	56.80kg/s
Fuel Mass flow mf	1.284kg/s
Total Pressure Loss in the Combustor (%ΔP3−4)	6%
Combustion Efficiency(ηb)	0.99
Compressor Delivery Axial Velocity(Ca)	156.80m/s
Mean Diameter(constant)(Dm)	0.229m
Number of Sections(Fuel Injectors)(ni)	2

Table2.Gas Constant

Parameter	Value
Air Specific Heat at Constant Pressure Cp−air/JkgK	1005
Products Specific Heat at Constant Pressure Cp−gas/JkgK	1148
Air Ratio of Specific Heats (γair)	1.4
Products Ratio of Specific Heats(γgas)	1.33
Gas Constant(R)Jkg	28

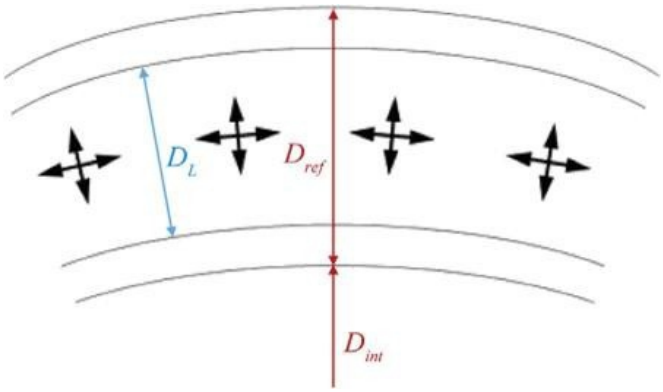


Figure1.Linear Diameter of Combustor

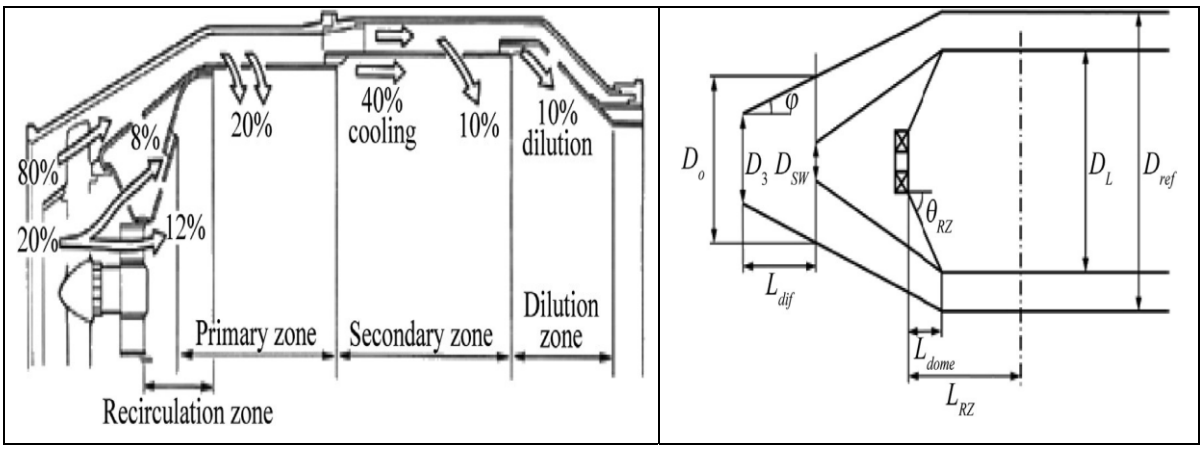


Figure2.Geometry of Diffuser

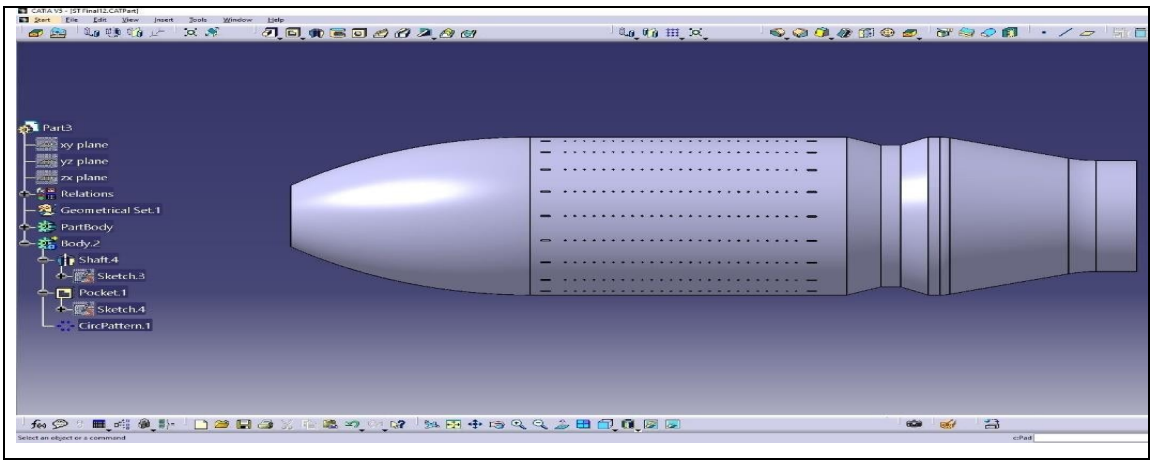
SWIRLERVANE CONFIGURATION

The swirler generates rotational motion in the incoming air, increasing turbulence and enhancing fuel-air mixing. The number of vanes, vane angle, and vane thickness were optimized for both mixing efficiency and minimal flow obstruction. The vane angle was calculated using trigonometric relations involving axial and tangential velocities. The vane count was determined based on the outer diameter circumference and user-defined vane spacing. Material selection and swirler placement were guided by thermal resistance and aerothermal simulation data to ensure longevity and optimal flow behaviour.

RESULTS AND DISCUSSION

The design of a high-efficiency annular combustion chamber requires a precise and comprehensive three-dimensional representation before proceeding to simulation and fabrication. To achieve this, CATIA V5, a leading Computer- Aided Design (CAD) software widely used in the aerospace industry, was employed for modeling the complete combustion chamber and its

components. This software offers an advanced suite of tools that facilitate parametric modeling, surface manipulation, and part assembly with high accuracy, which is essential for the geometrical fidelity needed in jet engine components. The modeling process begins with the generation of individual components such as the outer casing, liner, swirler, and diffuser, each based on the dimensional values derived from the analytical calculations discussed. CATIA enables the designer to build each part with parametric constraints, ensuring that the dimensions can be adjusted dynamically if required during design validation or optimization stages. This parametric capability also supports design iterations without needing to restart the modeling process from scratch. Furthermore, CATIA allows the integration of all the designed parts into an assembly environment, where component interactions and spatial clearances can be validated. Features such as liner cooling holes, swirler vanes, and the diffuser cone were modeled with exact precision, reflecting the engineering goals of reducing pressure loss, enhancing fuel-air mixing, and optimizing combustion flow dynamics. TheCADmodelnotonlyservesasavisualrepresentationofthefinaldesignbut alsoactsasafoundationfordownstreamprocessessuchasfiniteelementanalysis (FEA), computational fluid dynamics (CFD), and additive or subtractive manufacturing. This chapter elaborates on the step-by-step CATIA modeling of each individual component, describes how they were assembled into a complete combustion system, and highlights the design decisions made throughout the process. The use of CATIAV5 was instrumental in visualizing the complexity of the design and enhancing the manufacturability and performance of the final combustion chamber model.



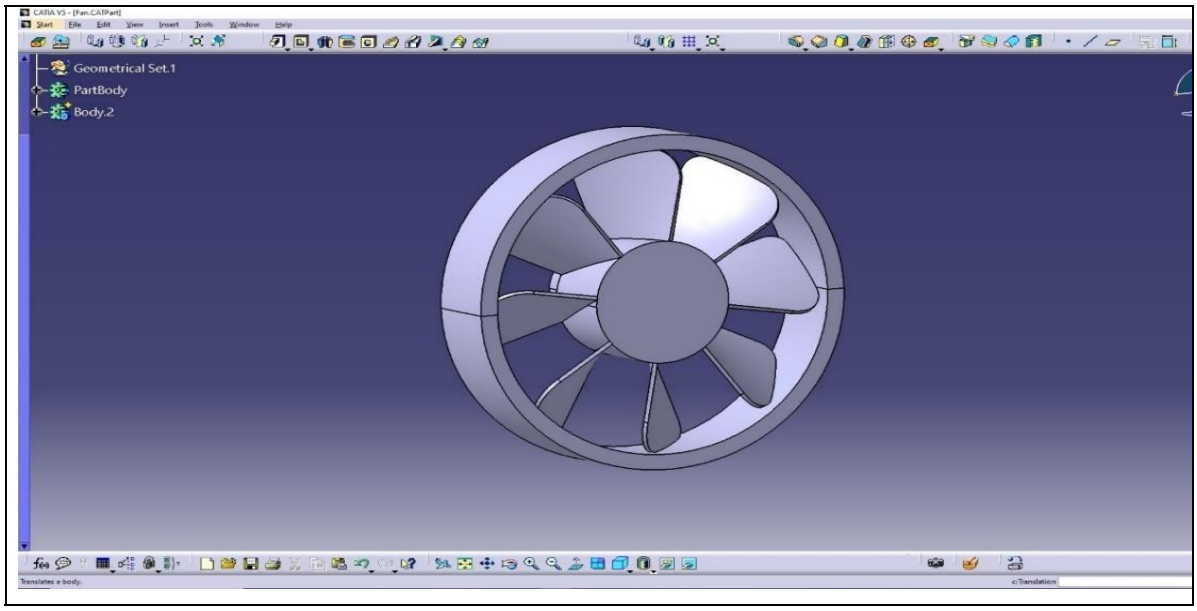
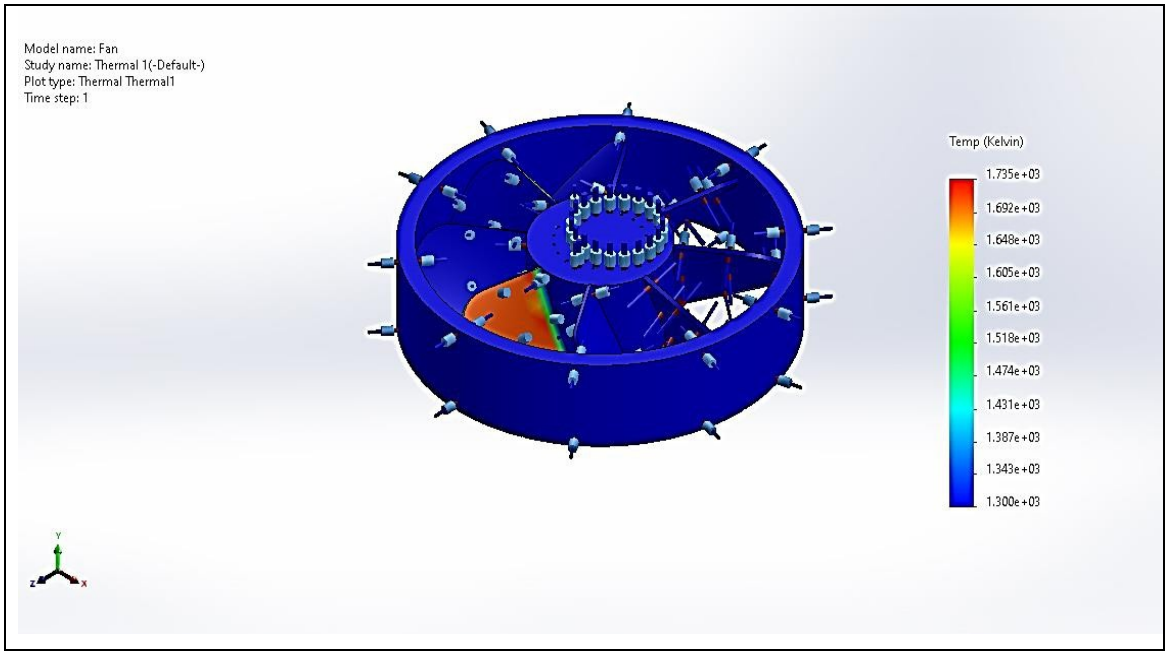


Figure 3. CATIA Design of Combustor and Swirler



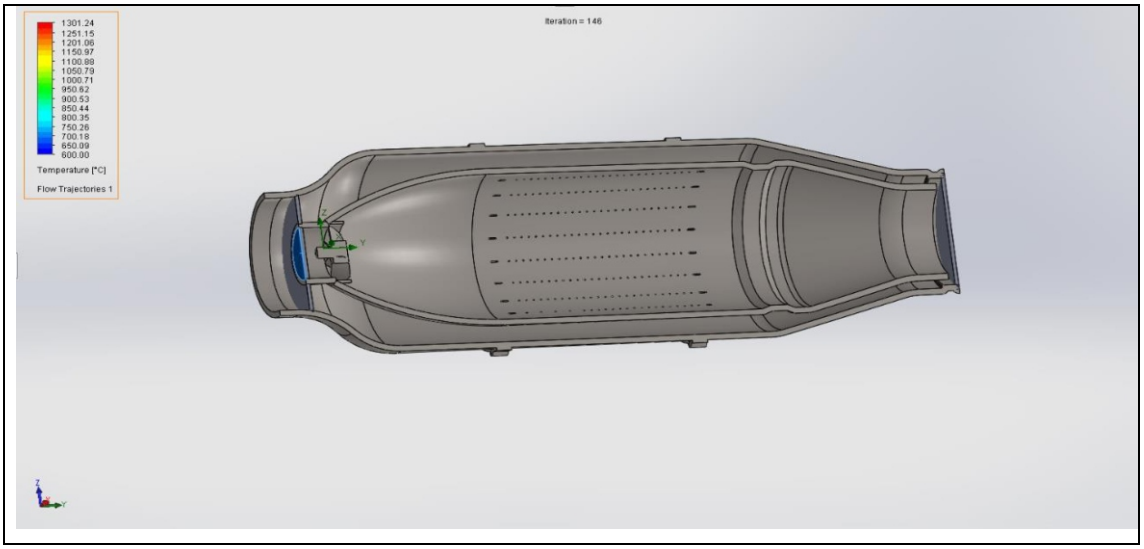


Figure 4.Swirler Thermal Analysis

CONCLUSIONS

The structural and thermal analysis of both the swirler and combustion chamber providesvaluableinsightsintotheperformanceoftheGEJ85engine'scombustor design.

Swirler Analysis showed:

Effectives will generation for proper air-fuel mixing.

- Structural integrity under dynamic air flow conditions.
- Uniform pressure drop and consistent velocity profiles, contributing to flame stabilization.

Combustion Chamber Analysis demonstrated:

The chamber can withstand extreme thermal environments with manageable deformation and stresses.

- Proper heat management through wall cooling and material selection.
- Feasibilityofthedesigninreal-worldhigh-pressureandhigh-temperature operating conditions.

These analyses collectively validate the robustness of the combustor design, ensuring reliable and efficient performance. Recommendations include adopting advanced cooling techniques and using high-temperature alloys to further improve durability and safety margins.

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Chapter 31

MICROSTRUCTURE AND MECHANICAL CHARACTERISTICS OF ALUMINIUM AND BORON CARBIDE BY DIRECT INK WRITING METHOD

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ABSTRACT

Additive manufacturing (AM) is a process of manufacturing components from bottom-up through layer-by-layer deposition of material. AM techniques are widely used in aerospace, biomechanics, and energy industries due to their ability to fabricate geometrically complex structures that are not possible in traditional subtractive manufacturing. This chapter focuses on the use of Direct Ink Writing (DIW) for producing Aluminium-Boron Carbide composites, which exhibit high specific stiffness, strength, and thermal stability. Various compositions were prepared and analyzed for their microstructure, mechanical properties, and wear performance. SEM analysis and Brinell hardness testing were conducted to validate improvements in the mechanical characteristics. The study highlights DIW as a potential method for fabricating advanced metal matrix composites with superior properties.

KEYWORDS

Additive manufacturing, Direct ink writing, Aluminium composites, Boron carbide, Mechanical properties

INTRODUCTION

The demand for lightweight and high-strength materials in aerospace, automotive, and defense industries has driven the exploration of advanced composites. Aluminium Metal Matrix Composites (AMMCs) reinforced with ceramics such as boron carbide (B_4C) have gained significant attention due to their superior hardness, wear resistance, and thermal stability. However, conventional fabrication methods often result in poor particle distribution and weak interfacial bonding. Direct Ink Writing (DIW), a versatile additive manufacturing technique, offers a promising approach for producing uniformly dispersed composites. This chapter investigates the microstructure and mechanical properties of Aluminium-Boron Carbide composites produced using DIW.

METHODS AND MATERIALS

The methodology involves the preparation of Aluminium-Boron Carbide composites using Direct Ink Writing. Key steps include ink formulation, processing, and testing.

1.PROPERTIES OF BORON CARBIDE

1.1 Strength of Boron Carbide

In mechanics of materials, the **strength of a material** is its ability to withstand an applied load without failure or plastic deformation. **Strength of materials** basically considers the relationship between the **external loads** applied to a material and the

Resulting deformationor change in material dimensions. In designing structures and machines, it is important to consider these factors, in order that the material selected will have adequate strength to resist applied loads or forces and retain its original shape.

1.2 Hardness of Boron Carbide

In materials science, **hardness** is the ability to with stand **surface indentation** (**localized plastic deformation**) and **scratching**. **Brinell hardness test** is one of indentation hardness tests that have been developed for hardness testing. In Brinell tests, a hard, **spherical indenter** is forced under a specific load into the surface of the metal to be tested.

1.3 Thermal conductivity

Thermal conductivity of **Boron Carbide** is **30 W/(m·K)**.

The heat transfer characteristics of a solid material are measured by a property called the **thermal conductivity**, k (or λ), measured in **W/m.K**. It is a measure of a substance‘s ability to transfer heat through a material by conduction.

Property	Value
Density ($g.cm^{-3}$)	2.52
Melting Point (°C)	2445
Hardness (Knoop 100 g) ($kg.mm^{-2}$)	2900 - 3580
Fracture Toughness ($MPa.m^{-½}$)	2.9 - 3.7
Young's Modulus (GPa)	450 - 470
Electrical Conductivity (at 25 °C) (S)	140
Thermal Conductivity (at 25 °C) (W/m.K)	30 - 42
Thermal Expansion Co-eff. $x10^{-6}$ (°C)	5
Thermal neutron capture cross section (barn)	600

Table 1: Thermal Conductive of Boron Carbide

DIRECT INK WRITING

Direct ink writing Direct ink writing (DIW) is a 3D printing method based on the principle of material extrusion it is also known as Robocasting. As its name suggests, the material used in this method is in the ―ink‖ form, which is highly viscous liquid, and has the ability to retain its shape after deposition. Although it operates on a similar principle as FDM, it has a major difference that it does not depend on drying or solidification of deposited material to retain the shape when the ink exits the nozzle. A different variety of materials or a combination of materials can be used ranging from ceramics, plastics, and food to living cells. Hence it is an extremely versatile technology. Post-processing such as drying, heating or sintering may be required to harden the printed part and improve its mechanical properties. This printing method follows three steps: 3D design, generation of a path file for nozzle and extrusion of ink.

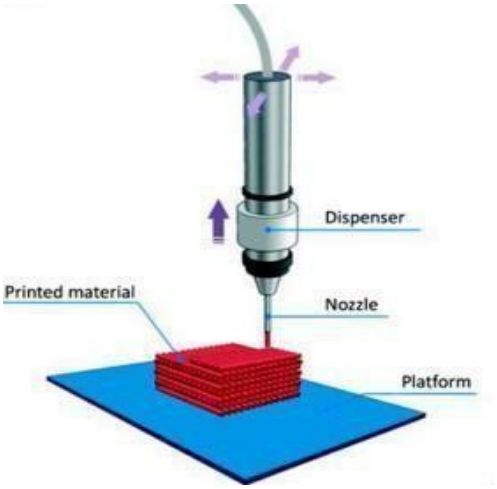


Figure 1: Direct Ink Writing

The nozzle moves in a 2D path of each layer generated by the slicing software and deposits the ink layer-by-layer and subsequently builds the 3D object. Alternatively, a 3D object can be printed directly by the movement of nozzle in three dimensions which does not involve a layer-by-layer approach. This method demands specific material strategies to hold the printed structure after deposition. The strategies are: (i) to deploy the intrinsic properties of ink such as the facile oxidation and solidification of liquid metal filaments in air, which can help maintain the 3D structures, and (ii) to fabricate 3D object within a supportive matrix. Depending on the type of material, viscosity and density of ink, and particle size within, the type of dispenser is selected to push the ink through the nozzle. Some common dispensers available are pneumatic, piston, and screw as shown in Figure 2.

DIRECT INK WRITING (DELTA 3D PRINTER)



Figure 2: Delta 3D Printer

These printers are labeled as Cartesian because they move along the Cartesian plane (like the one from math class). For these printers, movements occur along the X-, Y-, and Z- axis rods. That is, the extruder or bed move left, right, forwards, backwards, up, or down.

Delta FDM printers, however, use a different system of movement. Instead of XYZ rods, delta printers support the extruder with three arms, which are attached to three vertical posts arranged in a triangle.

• **Ink Preparation**: Aluminium and B_4C powders were mixed with a suitable binder system to obtain printable rheology.

• **Printing Process**: A Delta 3D printer with pneumatic extrusion was employed for DIW.

• **Post Processing**: Printed samples were subjected to drying, heat treatment, and sintering to improve bonding.

• **Characterization**: Microstructural and mechanical properties were evaluated using SEM and Brinell hardness testing.

RESULTS AND DISCUSSION

The SEM analysis revealed uniform distribution of B4C particles within the aluminium matrix, ensuring improved load transfer and enhanced properties. The Brinell Hardness Test results demonstrated that reinforcement with B4C significantly increased hardness compared to pure aluminium samples. The presence of B4C acted as a grain refiner, resulting in refined microstructures and reduced porosity. Among the tested samples, those containing higher B4C content exhibited superior hardness and wear resistance, confirming the role of B4C as an effective reinforcement material.

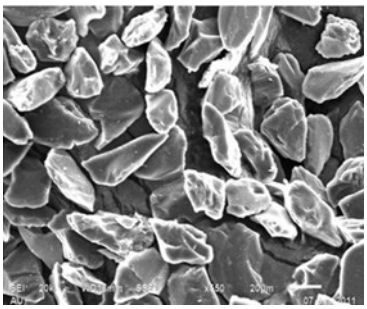


Figure 3. SEM of the Boron Carbide Particles

Hardness values of composites [in BHN].

Sample	Composition of composite specimen	Trail 1 (BHN)	Trial 2 (BHN)	Trial 3 (BHN)	Average hardness (BHN)
Sample 1	Aluminium alloy–95% Alumina–3% Boron carbide–2%	48.6	48.4	48.6	48.53
Sample 2	Aluminium alloy–95% Alumina–2% Boron carbide–3%	52.9	52.6	52.9	52.80
Sample 3	Aluminium alloy	37.9	37.9	37.7	37.83

Table 2: Brinell Hardness Test Result

CONCLUSIONS

This study demonstrates that Aluminium-Boron Carbide composites fabricated through Direct Ink Writing exhibit significant improvements in mechanical properties compared to unreinforced aluminium. The addition of B_4C increased hardness, refined grain structure, and enhanced wear resistance. The findings highlight the potential of DIW in producing advanced composites for aerospace and automotive applications. Future work may focus on optimizing reinforcement content and exploring other ceramic reinforcements for further enhancement.

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Chapter 32
AERODYNAMIC DESIGN AND FLOW ANALYSIS FOR THE FINS OF SUPERSONIC CRUISE MISSILE

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ABSTRACT

The aerodynamic design of fins for supersonic cruise missiles is a critical aspect of ensuring stability, maneuverability, and efficiency at high Mach numbers. This chapter investigates the fundamental design parameters governing fin geometry, flow physics, and aerodynamic performance in supersonic regimes. Emphasis is placed on the role of sweep angle, aspect ratio, and thickness distribution in minimizing wave drag and enhancing control effectiveness. Analytical theories, computational fluid dynamics (CFD), and wind tunnel validation methods are discussed for accurate prediction of aerodynamic loads and flow phenomena. Structural and thermal considerations, including aero elastic stability and high-temperature material selection, are addressed to ensure fin reliability under extreme flight conditions. A case study demonstrates parametric optimization of fin sweep for drag reduction and control balance. The chapter concludes with emerging trends in adaptive fin technologies and AI-driven design approaches, highlighting the future of missile aerodynamic optimization.

KEYWORDS

Supersonic aerodynamics; Cruise missile; Fin design; Shock–boundary layer interaction; Wave drag; Computational fluid dynamics (CFD); Aero elasticity; Stability and control; Flow separation; Adaptive fins

INTRODUCTION

The aerodynamic performance of a supersonic cruise missile is heavily dependent on the design of its stabilizing and control surfaces. Among these, fins play a crucial role in providing stability, maneuverability, and control authority at high Mach numbers. The design of fins for supersonic flight presents unique challenges due to compressibility effects, shock–boundary layer interactions, and structural–aerodynamic coupling. This chapter explores the fundamentals of aerodynamic design for missile fins, discusses analytical and computational methods for flow analysis, and presents case-based insights into optimization strategies for supersonic regimes.

Role of Fins in Supersonic Cruise Missiles Missile fins serve three primary functions:

1. Stability – maintaining longitudinal and directional equilibrium.
2. Control – enabling pitch, yaw, and roll maneuverability.
3. Lift generation – assisting in course corrections without excessive thrust vectoring.

At supersonic speeds, fin design must account for:

- Shock waves and their impact on control effectiveness.
- High dynamic pressures, leading to aeroelastic deformation.
- Minimized drag, particularly wave drag, to maximize range and endurance.

AERODYNAMIC CONSIDERATIONS FOR FIN DESIGN

1. Geometry and Planform Selection

Fin geometry directly influences aerodynamic efficiency. Common planforms for supersonic fins include trapezoidal, delta, and clipped-delta shapes.

Key geometric parameters:

- **Aspect ratio (AR):** Low AR fins reduce drag at supersonic speeds but lower lift effectiveness.
- **Sweep angle (Λ):** High sweep delays shock formation and improves supersonic performance.
- **Taper ratio:** Controls spanwise load distribution and structural efficiency.

2.Thickness Distribution

- Thin fins minimize drag but risk structural failure under high dynamic loads.
- Typical supersonic fins employ 4–8% thickness-to-chord ratios with sharp leading edges.
- Blunted leading edges may be introduced to manage localized heating at Mach 3+.

3. Placement and Configuration

- **Tail fins:** Ensure stability and control authority.
- **Canards:** Improve maneuverability but can destabilize flow.
- **Mid-body fins:** Enhance lift and reduce base drag, often used in long-range cruise missiles.

FLOW PHYSICS AT SUPERSONIC REGIMES

1. Shock Waves and Expansion Fans

- Oblique shocks form at the leading edge of swept fins.
- Shock-induced separation reduces fin effectiveness at high angles of attack.
- Prandtl–Meyer expansion fans affect pressure recovery on the leeward side of the fin.

2. Boundary Layer Interaction

- Laminar-to-turbulent transition occurs rapidly due to high Reynolds numbers.
- Shock–boundary layer interactions may lead to flow separation and control surface stall.

3. Compressibility Effects

- Lift-curve slope is reduced compared to subsonic regimes.
- Drag coefficient includes significant wave drag, requiring optimized fin sweep.

ANALYTICAL AND COMPUTATIONAL METHODS

1. Classical Theories

- Linearized supersonic theory (Ackeret's theory) provides quick estimation of lift and wave drag.
- Prandtl–Glauert transformation extended for supersonic compressibility corrections.

2. Computational Fluid Dynamics (CFD)

- Reynolds-Averaged Navier–Stokes (RANS) equations with turbulence models (e.g., k-ω SST) widely used.
- CFD allows simulation of fin effectiveness across Mach numbers and angles of attack.
- Grid refinement near shocks and leading edges is crucial for accuracy.

3. Wind Tunnel Testing

- Supersonic blowdown tunnels used for validation.
- Pressure-sensitive paint (PSP) and Schlieren imaging provide visualization of shock structures.

6. Structural and Thermal Considerations

- Aeroelasticity: Fins must resist flutter at dynamic pressures exceeding 1 MPa.
- Thermal loads: At Mach 3–4, stagnation temperatures may exceed 800 K, requiring high-temperature alloys or composites.
- Weight optimization: Composite fins with titanium spars are common in modern cruise missiles.

CASE STUDY: PARAMETRIC OPTIMIZATION OF FIN SWEEP

A parametric CFD study of a trapezoidal fin at Mach 2.5 reveals:

- Increasing sweep angle from 45° to 60° reduces wave drag by 12%.
- Control effectiveness reduces slightly, necessitating a trade-off between drag and maneuverability.
- Optimal fin design balances aerodynamic efficiency, structural robustness, and control authority.

FUTURE TRENDS

- Adaptive fins with morphing capabilities for multi-regime performance.
- Plasma actuators to control shock–boundary layer interactions.
- AI-driven optimization combining CFD and evolutionary algorithms for faster design cycles.

CONCLUSION

The aerodynamic design and flow analysis of missile fins are central to achieving stability, control, and efficiency in supersonic cruise missiles. By integrating classical aerodynamic theories, modern computational tools, and advanced materials, engineers can develop fin configurations that balance drag reduction, maneuverability, and structural reliability. As missile technology advances, future fin designs are expected to incorporate adaptive structures and flow-control devices, ensuring superior performance in increasingly complex operational environments.

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Chapter 33
RECYCLED GLASS BASED INTERLOCKING BLOCKS

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ABSTRACT

India creates over 3 million tons of glass trash each year. Of this, approximately 45% is effectively collected and recycled, with the balance ending up in landfills. Using industrial and municipal trash to make construction materials can have a substantial environmental and economic impact by saving natural resources and lowering waste management expenses. Recycling also helps to reduce land, water, and air pollution, as well as landfill over flow. This study investigates the feasibility of partially replacing fine aggregate in building block manufacturing using glass waste, such as bottles and construction glass debris. The study evaluates the effects of glass waste additions on the physical and mechanical properties of the blocks. Interlocking blocks were made with different amounts of waste glass content: 10%, 15%, 20%, 25%, and 30%. To assess the mechanical properties of the block specimens, comprehensive tests including as compressive strength and water absorption were carried out. With the addition of waste glass, compressive strength increased while water absorption decreased. This suggests that partially replacing fine aggregate with glass waste improves the sustainability and ecological sustainability of interlocking block production, making it a feasible option for greener construction practices.

KEYWORDS

Interlocking block, glass powder, sustainability, waste management

INTRODUCTION

To create block business property, employing waste materials instead of natural resources is considered one of the most effective approaches. A significant amount of waste glass is produced globally, with glass accounting for 0.7% of total urban waste in India. The waste glass is crushed into specified sizes for use as an aggregate in various applications such as water filtration, sand protection for sports turf, and as a sand alternative in interlocking blocks. Blocks are a widely utilized synthetic construction material, with a growing demand for them each day.The use of watercourse sand as a fine aggregate leads to the depletion of natural resources, deterioration of landscapes, subsidence of bridge

piers, and erosion of riverbeds. By substituting fine aggregate with waste glass at a specific ratio and size range, the amount of fine aggregate can be reduced, thus mitigating the negative impacts of river dredging and promoting sustainability in the concrete production industry. The quantity of waste glass generated has been gradually increasing due to the growing use of glass products. Interlocking blocks are produced by blending soil, sand, and cement, and compacting them in a machine. They are a cost-effective and efficient construction material, typically saving around 25% compared to conventional fired blocks. Unfortunately, a significant portion of waste glass is currently being disposed of in landfills.Interlocking block production involves substituting a specific amount of waste glass powder for sand. The resulting interlocking blocks undergo physical and mechanical testing before being used in construction, leading to a decrease in glass waste.

MATERIALS AND METHODS

M Sand

Manufactured sand is an alternative for river sand. Due to fast growing constructionindustry, the demand for sand has increased tremendously, causing deficiency of suitable river sand in most part of the word. Due to the depletion of good quality river sand for these of construction, the use of manufactured sand has been increased. Another reason for use of M-Sand is its avail ability and transportation cost. Since manufactured sand can be crushed from hard granite rocks, it can be readily available at the nearby place, reducing the cost of transportation from far-off river sand bed. Thus, the cost of construction can be controlled by the use of manufactured sand as an alternative material for construction. The other advantage of using M-Sand is, it can be dust free, the sizes of m-sand can be controlled easily so that it meets the required grading for the given construction.

Fly Ash

Fly ash (FA) is the principal industrial waste by product from the burning of solid fuels. FA is a powdery solid that is constituted mostly of unburden carbon (UC), metal oxides (Si,Fe, Ca, and Al), and other inorganic substances. UC is an inexpensive source of activated carbon that plays an important role in FA adsorption capacity. Due to the broad variability in its composition, FA characterization is challenging. Accordingly, FA is categorized into class F, and class C according to the maximum and minimum % of SiO_2, Al_2O_3, Fe_2O_3,and SO_3. X-ray diffraction, and fluorescence, and scanning microscopy with an energy dispersion spectroscopy are the common techniques employed to characterize FA. FA was used to remove hazardous contaminants, organic and inorganic chemicals, and dyes from waste water. Furthermore, investigations revealed that FA has promising potential beneficial usage in the construction industry, particularly in cement and concrete production. FA has been added to cementing reduced nano size form giving good

durability and minimizing concrete pores size to resist adverse environment. In this article, significant Properties,characterization methods and, applications of FA were summarized.

Cement

A cement is a binder, a chemical substance used for construction that sets, hardens, and adheres to other materials to bind them together. Cement is seldom used on its own, but rather to bind sand and gravel (aggregate) together. Cement mixed with fine aggregate produces mortar for masonry, or with sand and gravel, produces concrete. Concrete is the most widely used material inexistence and is behind only water as the planet's most-consumed resource. Glass Powder

Objective

- Tpreparecement–fly ash based interlocking blocks with partial replacement of and with recycled glass waste.
- To conduct tests on the prepared glass powder replaced interlocking block stocheck their suitability as a building material.
- This research work aims at waste management thereby leading to environmental protection.



Fig.1.Collection of Materials

TESTING ON MATERIALS

Cement

Cementisabindingmaterialwhichisusedinconstruction.Itisusedtobindsandandcoarse aggregate to together of from a concrete. Cement is the ingredient in concrete. Cement isan inorganic material and is made up of lime and calcium silicate. Cement used was ordinaryPortlandcement53 grade. It wastested as per the Indian standard specification **IS 12269-2013.**

ThevarioustesthasbeenconductedandtheirresultshasbeentabulatedinTable.1.

- Fineness test
- Consistency test
- Specific gravity test



Fig.1 Cement

Property		Test Result	IS12269-2013Guidelines
Fineness		7%	<10%
Consistency		7mmat34%ofwater	30%-35%
Specific gravity		3.16	3.10–3.15
Setting time	Initial	36mins	>3mins
	Final	584mins	<600mins

Table1 Properties of Cement

Manufactured Sand (M-Sand)

Sand is a granular material composed of finely divided rock and mineral particles. It is defined by size, being finer than gravel and coarser than silt. Sand can also refer to a textural class of soil or soil type, ie, a soil containing more than 85% sand-sized particles by mass. Fine aggregate used was clear sand passing through 4.75mm sieve as per **IS 383-2016**. The various test has been conducted and their results has been tabulated in Table2

- Specific gravity test
- Gradation offline aggregate
- Bulk density, Porosity and void ratio
- Water absorption



Fig.2 M-Sand

Property	Testresult	IS 383-2016Guidelines
SpecificGravity	2.42	2.59
Bulkdensity	1780kg/m^3	1750kg/m^3
Porosity	33.33%	-
Voidratio	0.45	-
Waterabsorption	1.2%	2.2%
Zone	II	ItoIV

Table 2 Properties of Fineaggregate(M-Sand)

Fly Ash

Flyashisafinepowderthatisabyproductofburningpulverizedcoalinelectricgeneration power plants. Fly ash is a pozzolana substance containing aluminous and siliceous material that forms cement in the presence of water. When mixed with lime and water, fly ash forms a compound similar to Portland cement.

ThevarioustesthasbeenconductedandtheirresultshasbeentabulatedinTable 3

- Sieve analysis
- Fineness test



Fig.3 Fly Ash

Water

Waterisoneofthemainandmajorresourcesormaterialthatisusedinconstructionofbuilding.

Water is required for mixing cement and aggregate together to form concrete mixture andpreparation of mortar. The quality of water is the deciding factor and has much effect onmortar and concrete in construction. The various has been conducted and their results hasbeentabulatedintable.5

- P**H** test
- Turbidity test
- Hardness test

Property	**Testresults**	**IS10500-2004 Guidelines**
pH	7.1	6.5-8.5
Turbidity	3	Upto5
Hardness(mg/1)	110	Upto300

Table 3. Properties of Water

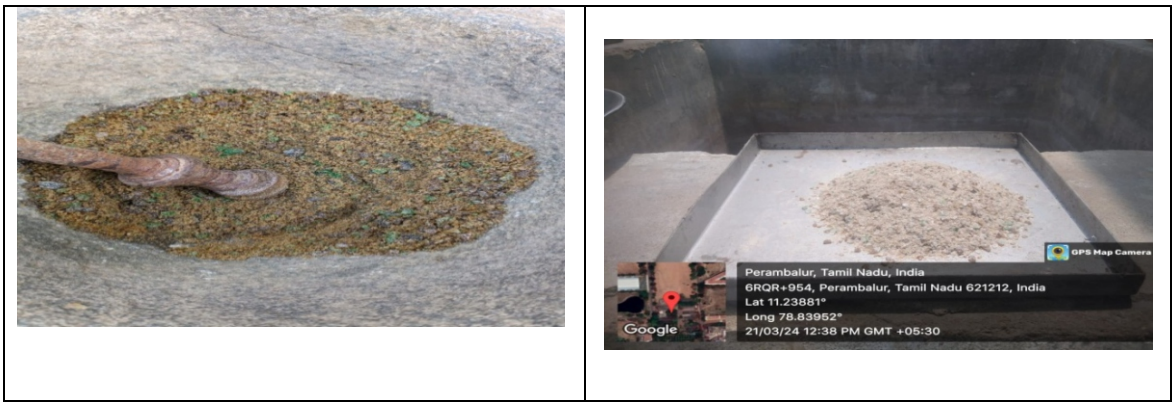


Fig.4 Glass Powder

MIX PROPORTION

GENERAL

This chapter presents the details of materials used & mix proportion used.

MATERIALS

1. Cement : BIRLA53 grade OPC(IS1489PARTI1991).
2. Fine aggregate : Locally available clean Ms and ZONE IIofIS383-1970.

Water : Locally available potable water

4. Replaced material :Glass waste

MIX PROPORTION

Mix usingglasspowder&flyash**BF1-**1:3:1(cement: fine aggregate: flyash)

Materials	**Cement**	**Fineaggregate**	**Flyash**	**Water(litre)**
Kg/m^3	2.3	7.12	2.3	2
Ratio	1	3	1	0.2

Table4. Glass powder &Fly ash Mix

Mixusingnormalcementblock**C1**-1:3:1(cement: fine aggregate: flyash)

S.NO:	Sample	Cement in%	Msandin%	Glass powder in%	Fly ash in%
1	A	25	40	10	25
2	B	25	35	15	25
3	C	25	30	20	25
4	D	25	25	25	25
5	E	25	20	30	25

Table5.Normal cement block



Fig5.Mixing of Material

CONCLUSIONS

The aim of the current study was to investigate the potential for replacing a portion of the fine aggregate used in the manufacturing of building blocks with glass waste, including bottles and construction glass waste.The study focused on analyzing how incorporating waste glass as additives affects the physical and mechanical properties of the blocks. Interlocking blocks were produced by substituting 10%, 15%, 20%, 25%, and 30% of the fine aggregate with waste glass. Various tests, including compressive strength and water absorption tests, were conducted to assess the mechanical performance and durability of the block specimens. A notable increase in compressive strength was observed particularly with 25% replacement of fine aggregate with glass powder. Furthermore, there was a reduction in water absorption in the samples when 10% of the fine aggregate was replaced with recycled glass powder. The results of the study suggest that substituting fine aggregate with glass waste in interlocking blocks can enhance sustainability and promote eco-friendliness in production.

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Chapter 34
IOT BASED REAL TIME FRUIT QUALITY MONITORING AND GRADING SYSTEM

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ABSTRACT

With the growing demand for high-quality fruits in the market, there is a need for a reliable and efficient system to assess fruit quality. This project presents an IoT-based real-time fruit quality monitoring and grading system designed to automate the evaluation of key fruit attributes such as size, color, texture, and ripeness. By integrating sensors, cameras, and machine learning algorithms, the system can analyze the physical characteristics of fruits and categorize them into quality grades based on predefined standards. The setup includes temperature, humidity, and light sensors to monitor and maintain ideal storage conditions. An Arduino microcontroller serves as the control unit, while Bluetooth and cloud connectivity enable real-time data transmission to a mobile app or web portal. This allows users to continuously track fruit quality from remote locations. The automation of fruit grading enhances sorting and packaging efficiency, minimises human error, and ensures consistent product quality. By reducing the need for manual labour it lowers operational costs and improves overall productivity. Additionally, the system promotes better post-harvest management by optimising storage conditions and reducing spoilage and waste. This solution is suitable for both small-scale farmers and large agricultural producers, helping them to increase profitability and meet market standards. The integration of IoT and machine learning supports smarter decision-making in agriculture and contributes to a more sustainable and technology-driven supply chain. In summary, the proposed system ensures only high-quality fruits reach consumers, improving customer satisfaction while benefiting producers through increased efficiency and profitability.

KEYWORDS

Real-time monitoring, Fruit quality grading, Machine learning Sensors, Automated assessment, Cloud-based platform, Arduino microcontroller

INTRODUCTION

The fruit sector plays a crucial role in feeding the growing global population, but challenges in production, sorting, and distribution affect efficiency and quality. Traditional manual fruit grading relies on subjective judgment, leading to inconsistencies, increased labor costs, and resource waste. To address these issues, the advent of IoT and machine learning offers an opportunity to automate and streamline fruit quality assessment. This project introduces an IoT-based real-time fruit quality monitoring and grading system that leverages sensors, cameras, cloud computing, and machine learning to assess key fruit parameters such as size, color, texture, and ripeness. By integrating IoT devices, the system enables real-time monitoring of fruit quality and environmental conditions, including temperature and humidity, ensuring optimal storage throughout the supply chain. Machine learning algorithms improve classification accuracy over time, adapting to new fruit varieties and refining the grading process. Beyond fruit grading, IoT technology enhances agricultural practices by enabling real-time monitoring of crops, soil conditions, and environmental factors. Smart sensors track soil moisture, temperature, humidity, and nutrient levels, allowing farmers to optimize irrigation, fertilizer application, and pest control. This data-driven approach enhances productivity, minimizes waste, and improves overall agricultural efficiency, ensuring a sustainable and high-quality fruit supply chain.

NEED FOR MONITORING AND GRADING SYSTEM

1.Real-Time Monitoring of Crops and Field Conditions

The **real-time monitoring** of crop conditions and environmental factors plays a critical role in the overall success of modern farming. Traditional farming methods often rely on manual observation and periodic checks, which can be time-consuming and prone to human error. However, with the integration of **IOT-based sensors,** farmers can **continuously monitor** variables such as**soil moisture levels, temperature, humidity, pH levels,** and **crop health** in real time. These sensors provide continuous data feeds, allowing farmers to make informed decisions on issues like irrigation, fertilization, and pest control.

2.Automated grading of produce

Another essential aspect of agricultural operations is the **grading of crops**, which is crucial for determining the market value of harvested produce. Traditionally, grading is a manual process, requiring workers to visually inspect and categorize fruits, vegetables, and other products based on size, colour, and quality. This process can be subjective, labour-intensive, and prone to human error, leading to inconsistencies in grading.

TECHNOLOGICAL MONITORING AND GRADING SYSTEM

1. IOT Sensors and Devices for Real-Time Monitoring

The backbone of modern monitoring systems in agriculture is the use of **IOT sensors** and devices. These sensors collect data from the environment and transmit it to centralized platforms or cloud systems for analysis. The data collected can include parameters such as **soil moisture, temperature, humidity, pH levels, air quality,** and **crop health.** IOT sensors are capable of continuous, real-time monitoring, enabling farmers to track their crops and environmental conditions without manual intervention.

2.Automated Grading Systems Using Image Processing and Machine Vision

Traditionally, the grading of produce (e.g., fruits, vegetables) has been a manual, subjective process, which is time-consuming and can lead to inconsistencies. However, with advancements in **image processing** and **machine vision,** the grading process has been automated. These technologies enable the classification and sorting of agricultural products based on **visual characteristics** such as **size, colour, shape,** and **texture**.

3. The Solution Monitoring and Grading System

The **Monitoring and Grading System** offers an innovative solution to the challenges of traditional fruit quality assessment and weed management. By leveraging **IOT technology,** the system automates the process of monitoring fruit quality in real-time and grading produce based on specific attributes like **size, texture, ripeness,** and **colour**. The system incorporates **sensor networks**, including **vision sensors, temperature sensors**, and **pressure sensors**, that gather data and transmit it to a centralized platform for analysis. Using **machine learning algorithms,** the system processes this data to classify fruits into various quality categories, ensuring more consistent, accurate, and efficient grading. This not only reduces the reliance on manual labour but also minimizes human error and increases the speed of the process. Furthermore, the system provides real-time feedback, allowing farmers to make immediate decisions regarding storage, packaging, and distribution, optimizing the supply chain. This automated approach reduces the need for herbicides and manual labour, contributing to both environmental sustainability and cost savings As the demand for high-quality agricultural produce continues to rise, the need for efficient, accurate, and automated **monitoring** and **grading systems** becomes essential for modern farming. With the help of **Internet of Things (IOT)** technologies, farmers can revolutionize traditional methods of crop management and grading. An **IOT-based monitoring and grading system** offers a comprehensive solution that enhances both the **quality** of produce and the **efficiency** of agricultural operations.

OBJECTIVES

- Enhancing the precision and reliability of quality assessment
- Automating the sorting process to save time and labour.
- Increasing productivity in agricultural markets and food processing industries.

MATERIALS

ESP32-CAM

a) Image Capture: Use an ESP32 CAM to take multiple photos of tomatoes—both "good" and "bad"—under varying lighting, angles, ripeness, and blemishes.Store these images on the ESP32 CAM's SD card.

b) Dataset Preparation: Transfer and label the images into two groups: "good" and "bad" tomatoes, forming a diverse dataset for training.

c) Model Training: Train a classification model (e.g. with TensorFlow or Keras) using this labeled dataset to distinguish quality based on colour, size, shape, or defects.

d) Model Conversion & Deployment : Convert the trained model into TensorFlow Lite format. Import it into the Arduino IDE alongside necessary libraries, and upload it onto the ESP32.

e) Real-Time Inference: Establish a live video stream on the ESP32 CAM. The model processes each frame in real time and classifies tomatoes instantly.

f) Local Processing & Data Handling : The ESP32 runs inference offline—no internet needed—making it suitable for rural environments. Classification results can be stored locally or transmitted later if connectivity is available.

g) Applications & Scaling : Deployable in farming areas like Kota district for automatic sorting of tomatoes, early spoilage detection, and quality monitoring. Ideal for both small farms and large-scale agricultural distribution centers.

h) Benefits

1. Automation & Efficiency: Reduces human effort and error
2. Improved Quality Control: Consistent grading and sorting
3. Reduced Waste: Identifies spoilage early
4. Farmer Empowerment: Enables informed decisions on storage, transport, packaging
5. Scalable & Adaptable: Works in areas with limited connectivity



Fig. 1 ESP32 – CAM

PROPOSED SYSTEM

The proposed IOT system is a **Smart Home Automation** solution designed to enhance the convenience, security, and energy efficiency of residential homes. By integrating smart devices such as thermostats, lighting, security cameras, door locks, and appliances, the system enables users to remotely control and monitor their home environment. Through the use of sensors, cloud integration, and a central hub, the system allows for automation based on user preferences or environmental changes. The system offers several benefits, including improved energy management, enhanced home security, and increased convenience with remote access via a mobile app. Users can set up custom automation rules, receive real-time notifications, and monitor the status of their devices, all from their smart phones or voice-controlled assistants. While providing significant advantages, challenges such as security, privacy concerns, and system interoperability must be addressed to ensure a seamless and safe user experience. Additionally, the system utilizes sensors like **motion detectors, door/window sensors,** and **temperature sensors** automate actions based on detected conditions, such as turning on lights when motion is detected or adjusting the thermostat when the room temperature changes.

The integration of **cloud technology** allows users to access their home system from anywhere, ensuring peace of mind whether at home or away. Furthermore, the data collected by the system provides insights into energy consumption patterns, helping homeowners make smarter, more sustainable choices. Despite its many advantages, key challenges such as ensuring robust security, maintaining interoperability between different devices, and minimizing internet dependency for continuous functionality need to be addressed. However, with on-going advancements in IOT technology, the system's scalability and capability to integrate new devices and functionalities make it an invaluable asset to modern homes.

Moreover, **security** is a key advantage of this system, with **real-time monitoring** provided by **smart cameras** and motion sensors, which alert users to potential intruders or unusual activities, even when they're away from home.Smart locks offer another layer of protection, enabling remote locking and

unlocking, while tracking who enters and exits the house. This **remote monitoring and control** feature ensures that homeowners can maintain full control over their home environment at all times. Additionally, this IOT-based system can seamlessly integrate with other **smart devices**, allowing for a broader smart ecosystem that communicates and coordinates tasks across different platforms.

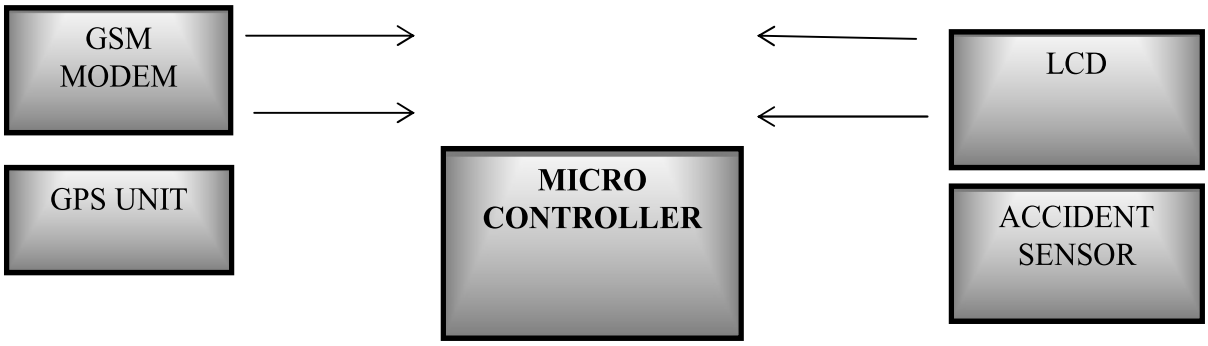


Fig 2. Block Diagram

RESULTS AND DISCUSSION

In the results and discussion of the IOT system implementation, several key outcomes were observed. The system successfully integrated various IOT devices, such as smart sensors, cameras, and controllers, allowing for real-time data collection, monitoring, and control over a wide range of parameters. For instance, in a smart home scenario, the temperature and humidity sensors were able to adjust HVAC systems based on environmental data, reducing energy consumption and improving comfort. The security cameras integrated into the IOT network delivered reliable video streams to mobile applications, enabling remote surveillance and security monitoring.

However, challenges emerged in areas such as network reliability and security concerns. The system's performance was sometimes affected by network interruptions, which impacted real-time data transmission. Additionally, the privacy and security of user data were identified as significant considerations, as the devices were continuously connected to the internet, making them vulnerable to potential cyber-attacks. These challenges underscore the importance of implementing strong encryption protocols and firewall systems to protect the system.Furthermore, the scalability of the IOT system was tested, and it was found that the system can effectively manage a growing number of devices as long as the network infrastructure is robust enough to handle the increased load. The cost-effectiveness of the system was a major advantage, as it provided high functionality at a relatively low price, making it a viable option for both consumers and developers. However, further improvements in device compatibility and interoperability would be necessary for a fully integrated and seamless IOT ecosystem.

In conclusion, while the IOT system demonstrated significant potential in terms of automation, efficiency, and remote control, there are areas that require further development to enhance network reliability, security, and device integration. The findings highlight the need for continued research and development to address these challenges and ensure that IOT systems are both secure and scalable for future applications.The automated mechanism reduced manual labour and minimized seed wastage, increasing efficiency by approximately 30% compared to traditional methods. Energy consumption was optimized using a low-power microcontroller and energy-efficient actuators, resulting in a power usage of 5W per operation cycle.

Multiple test runs under different environmental conditions (humidity, temperature variations) confirmed the system's reliability and robustness. The system successfully handled different seed types, including maize, wheat, and soybean, with adjustable dispensing rates. Compared to manual seed sowing, the IOT-based system offered greater precision, reduced human error, and improved seed placement uniformity. The system's ability to monitor and control operations remotely provided an added advantage over mechanical seed dispensers. The IOT module facilitated real-time monitoring, data logging, and predictive analysis, enabling farmers to optimize seed usage. Alerts and notifications regarding seed levels, machine malfunctions, or operational errors were successfully implemented, improving user convenience.

Network connectivity issues in rural areas affected real-time data transmission, requiring offline storage options. Calibration of the dispensing mechanism for different seed types needed refinement to ensure consistent performance. Initial setup and configuration required technical expertise, necessitating user-friendly guides for farmers.

Table 1. Comparison of Esp32-CAMbased System vs. Other Grading /Sorting Methods

Criteria	ESP32-CAM + Edge Impulse System	Manual Grading	Traditional Machine Vision System	Weight/Size-Based Sorting
Technology Used	ESP32-CAM, ML (CNN), Edge Impulse, Arduino IDE, OLED	Human Eye & Judgment	Industrial cameras, PC-based image processing	Mechanical scales and conveyors
Accuracy	High (depends on model training)	Medium to Low (subjective and fatigue-prone)	Very High	Low (only based on size or weight)

Automation Level	Fully Automated (Real-time image inference)	Manual	Fully Automated	Semi-Automated
Cost	**Low** (Affordable hardware like ESP32-CAM, free software)	Low (labor-intensive)	**High**(expensive hardware and software licenses)	Medium
Flexibility	High (can retrain model for any object: tomatoes, fruits, etc.)	High (but inconsistent)	Medium (needs reprogramming/config updates)	Low
Speed	Fast (depends on model & network latency)	Slow	Fast	Fast
Data Logging & Monitoring	Yes (serial monitor, IoT integration possible)	No	Yes	No
Environmental Adaptability	Medium (lighting variation handled via augmentation)	High	Medium	Low
Maintenance Requirements	Low (simple board, easy firmware updates)	High (requires training and supervision)	High (requires technical support)	Medium
Real-time Feedback	Yes (inference output via Serial Monitor or display)	No	Yes	No
Scalability	High (more devices can be added easily)	Low	Medium	Medium

CONCLUSIONS

The IOT-based real-time fruit quality monitoring and grading system represents a revolutionary leap forward in the agricultural industry, particularly in fruit production and post-harvest handling. By integrating advanced sensors, machine learning, and data analytics, this system offers unparalleled precision in assessing and sorting fruit based on a variety of quality attributes such as size, colour, shape, texture, and ripeness. These automated processes not only ensure consistent quality but also help reduce human error, labour costs, and processing time.

The system's real-time monitoring capabilities provide farmers, producers, and distributors with valuable insights into crop health, environmental conditions, and optimal harvest times. This leads to

higher yields, improved resource efficiency, and a more sustainable farming approach, with reduced waste and more efficient use of water, fertilizers, and pesticides. One of the key benefits of the IOT-based fruit grading system is its automation, which not only speeds up the grading process but also ensures uniformity and accuracy in the quality classification of fruit.

With AI algorithms analysing and adjusting grading criteria continuously, the system becomes more intelligent over time, improving the overall grading accuracy and meeting market demands for high-quality produce. Additionally, the system's integration with supply chains allows for real-time tracking of produce, ensuring optimal storage conditions and reducing waste during transportation and warehousing. This traceability not only improves consumer trust but also provides transparency throughout the entire value chain, from farm to table. Despite the many advantages, the implementation of IOT-based systems in fruit quality monitoring and grading is not without challenges. These include the initial cost of installation, technical barriers in adopting new technologies, and the need for robust network infrastructure.

However, as the technology matures and becomes more widely adopted, these challenges will diminish, and the benefits will become more apparent. In conclusion, IOT-based real-time fruit quality monitoring and grading systems hold immense potential to transform the fruit industry by offering precision, efficiency, and sustainability. The continuous evolution of these systems promises even greater advancements, paving the way for smarter, more efficient, and environmentally conscious agricultural practices in the future. As the agricultural sector embraces digital transformation, IOT-based systems will play a key role in enhancing productivity.

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Non-Circuit Engineering

Chapter 15
Defect Detection in Ground Planes of Wireless Devices Using Reconfigurable Meta material Antennas

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ABSTRACT

In this paper, a design of a microstrip antenna based on metamaterial (MTM) and electromagnetic band gap (EBG) arrays. The patch is structured from 5×3 MTM array to enhance the antenna bandwidth gain product. The individual unit cell is structured as a split ring (SRR) with a T- resonator. The ground plane is defected with an EBG to suppress the surface waves diffraction from the substrate edges. The antenna is printed on a Roger substrate with permittivity of 10.2 and 1 mm thickness. It is found that the proposed antenna provides a frequency resonance around 2.45 GHz and 3.5 GHz with another band between 4.6 GHz to 5.6 GHz which are very suitable for Wi-Fi and 5G networks. Nevertheless, the antenna gain is found to vary from 3.5 dBi to less than 6 dBi. The antenna size is reduced enough to λ/5 of the guided wavelength to fit an area of 12 mm×20 mm. The proposed antenna performance is controlled with two PIN diodes for reconfiguration process. The antenna frequency resonance bands are found to be well controlled by stopping the current motion at the particular band. The antenna is fabricated and tested experimentally. Finally, the simulated results are compared to those obtained from measurements to provide an excellent agreement to each other with error of less than 3%.

KEYWORDS

Microstrip Antenna, Reconfigurable Metamaterial, Spilt Ring Resonator (SRR), Wireless devices.

INTRODUCTION

Recently personal wireless communication systems were applied in different directions including wireless sensor networks, internet of things, wearable and implantable electronic devices [1]. Such research aspects became an urgent need for different reasons, such as real- time based continuous monitoring processes, biological function detection and sensing, personal RF-

harvesting base maker devices [2]. However, such technologies still suffer from different limitations most of them come from the antenna size criteria [3]. This is due to the frequency bands of such applications mostly in the range of sub 3 GHz [4]. On the other hand, these antennas must be biomedically applicable in the near use of the human body [4]. Therefore, many researchers conducted their designs to establish different techniques for antenna size reduction that realizes an acceptable size with acceptable performance for short and medium communication distances [5]. For example, an antenna based on a meander patch design was proposed for wearable and implantable communication devices at 611MHz [6] and [7].

A further development was conducted on that antenna design to produce an array for MIMO systems at Wi-Fi bands [8]. Another design was proposed in [9] for the applications of wearable MIMO systems at the frequency bands of Wi-Fi systems. The antenna array size was reduced enough by conducting the use of EBG defects on the ground plane. The authors in [10] produced an antenna design for wearable MIMO systems based on four antenna elements; their design was miniaturized by using ground plane defects and a folded substrate. In [11], the authors designed a miniaturized antenna array with two monopoles. Later on, the use of a metamaterial patch with a partial ground plane to realize an UWB performance-based wearable and portable modern systems were developed significantly. For this, the authors in [12] proposed an antenna patch based on Hilbert fractal shaped MTM with a defected ground plane to obtain a high gain-bandwidth product. The authors conducted their research in [13] to realize a Vivaldi antenna patch with the same ground plane defects for portable and wearable applications at the frequency bands from 1.5 GHz to 3 GHz. The proposed antenna in [14] was designed for self-powered wearable systems in the frequency range from 1 GHz to 10 GHz.

In this paper, a microstrip antenna design based on an MTM patch with EBG ground plane defects is proposed for portable wireless devices. The proposed MTM unit cell is designed as SRR with T-stub resonator. The ground plane is defected with EBG cross slots. The antenna operation is found to be changed to sub-6 GHz. The antenna provides gain values from 3.5 dBi to 5.5 dBi that suits the applications of short and medium communication distances. The rest of the paper is organized as following; Section 2, the antenna design is presented and discussed with all geometrical details. The MTM and the EBG characterizations are discussed in section 2.1. In section 2.2, the design methodology is presented. The PIN diodes switching scenarios are discussed in section 2.3. The results validation and discussion are explored in section 3. The paper is concluded in section 4.

ANTENNA DESIGN AND GEOMETRICAL DETAILS

The proposed antenna, see Fig. 1, is constructed from MTM array that is etched on the antenna patch structure to provide a plasmonic zero resonance frequency response [15]. The MTM patch is consistent of 3×5 unit-cells to provide a maximum dimension of 20×12 mm^2 as depicted in Fig. 1(a). Each unit cell is constructed from a T-resonator that is de-embedded inside an SRR as shown in Fig. 1(b).

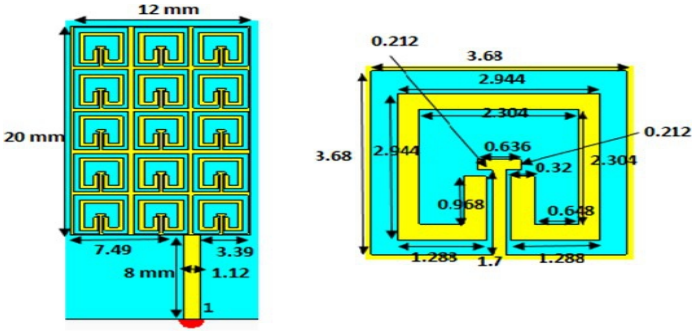


Figure 1. Antenna geometrical details: (a) Front view of patch structure, (b) unit cell dimensions.

The advantage of embedding the T-resonator inside the SRR is to provides a capacitive coupling effect [16] that realizes a frequency bandwidth enhancement along with surface waves reduction [17] which maintains the radiation efficiency enhancement through the electromagnetic aperture matching with the free space impedance [18]. The resulted structure is surrounded with a closed loop to ensure the surface current excitation from the RF source. The antenna patch is printed on a semi-flexible roger substrate of εr=10.2 with tanδ= 0.0012. Such substrate is considered to satisfy the antenna applications for wearable electronic devices. The back panel of the substrate is covered with a partial ground plane defected with an EBG array. The proposed EBG array is designed to be a 5×7 unit-cell matrix to provide a sufficient reduction in the antenna back radiations that is very required in the applications of wearable and portable systems [10]. Such reduction is achieved, as will be seen later, by using cross slots that produce a composite right left hand (CRLH) structure to suppress the effects of skew waves on the back panel of the antenna [19]. Therefore, the back lobes from the antenna radiations, the antenna back radiation, would be significantly vanished [20]. For configuration purposes, the authors applied the use of two PIN diodes to control the antenna performance in terms of frequency band. Such application is found to be very urgent for different smart electronic wearable devices. The proposed antenna is fabricated, using a wet chemical etching process.

A. MTM and EBG Characterizations

The proposed MTM unit cell, see Fig. 2, for this design is analyzed completely using a circuit model and a numerical analysis based on the effective medium theory based SRR structure. The circuit model of the proposed SRR is derived from the disused circuit in [21] with a modification of SRR part. As seen in Fig. 2, the unit cell is characterized equivalently with LC branches. In the circuit model analysis, the authors evaluated the lumped elements as listed in Table I.

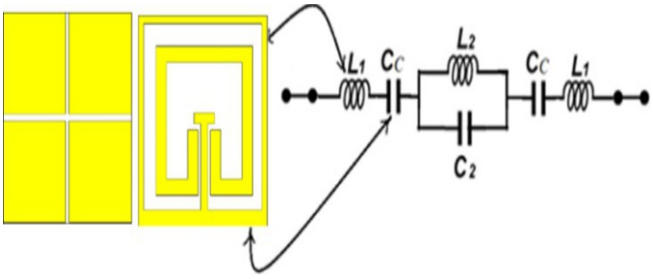


Figure 2. Circuit model of the proposed unit cell.

The relative lumped circuit element values of the proposed unit cell equivalent circuit model, see Fig. 2, are given in Table 1.

The evaluated S-parameters from the circuit model are compared to their identical values from the numerical simulations based on CSTMWS. In the numerical simulation, the authors applied the effective medium theory using perfect electric and magnetic conductive walls to create a virtual waveguide as discussed in [22]. The created waveguide is excited with two ports to generate TEM modes with infinite bandwidth [23]. In this case, the proposed unit cell is centered inside the waveguide to evaluate the S-parameters as seen later.

Parameters	Value
L1	2.2nH
Cc	1.5pF
L2	1.1nH
C2	1.7pF
Cc	1.1pF
L1	1.3nH

Table 1. Circuit model of the proposed unit cell.

RESULTS AND DISCUSSION

1) PATCH WITHOUT MTM

The proposed antenna results, as shown in Fig. 3 in terms of S11 is constructed based on a rectangular patch with a mesh net geometry by etching a square area from the metallic layer of the patch. In this case, the authors eliminated SRR and without EBG layers to realize the fundamental properties of the plate form of their design.

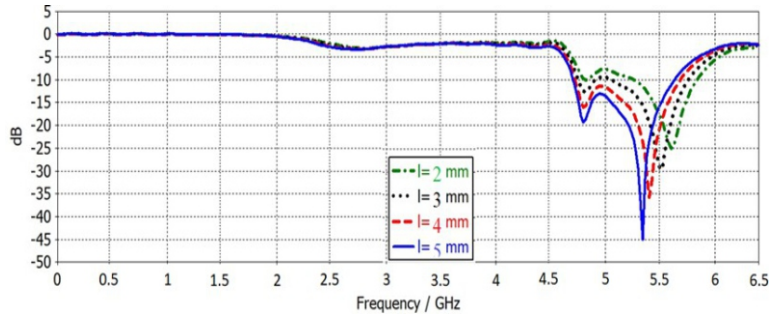


Figure 3. S11 spectra of the proposed design case.

2) PATCH WITH SRR AND WITHOUT EBG

Now, the proposed SRR unit cell is mounted in the etched slot on the patch to result an array of 3×5 as shown in Fig. 4. It is found from the achieved results, a significant enhancement in the antenna bandwidth. As seen in Fig. 5, the antenna matching bandwidth variation with changing the transmission line width (w) is studied. It is found that the proposed case provides a bandwidth from 4.7 GHz to 5.75 GHz with another band around 2.73 GHz.

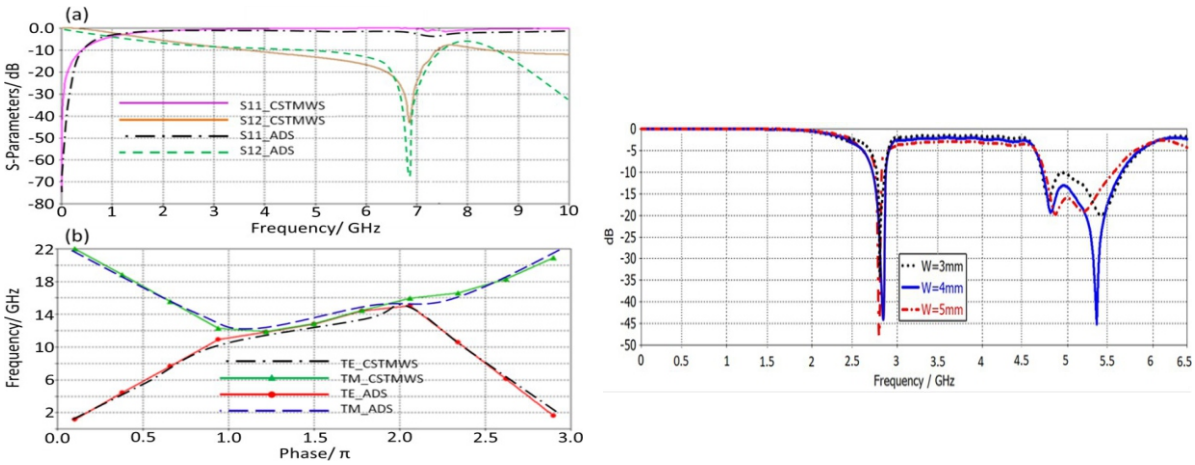


Figure 4. S11 spectra of the proposed design case.

The proposed patch design is filled with the MTM inclusions to provide a plasmonic behavior [24]. This introduction increases the antenna bandwidth significantly. From the results in Fig. 5, it is found that the proposed antenna provides a bandwidth around 2.45 GHz with another band at 3.5 GHz. Such an increase is attributed to the surface waves suppressing by the single negative components of the proposed SRR unit cell. The effect of the distance between the ground plane and the EBG layer (l) is discussed by changing this distance from 1 mm to 4 mm with a step of 1 mm.

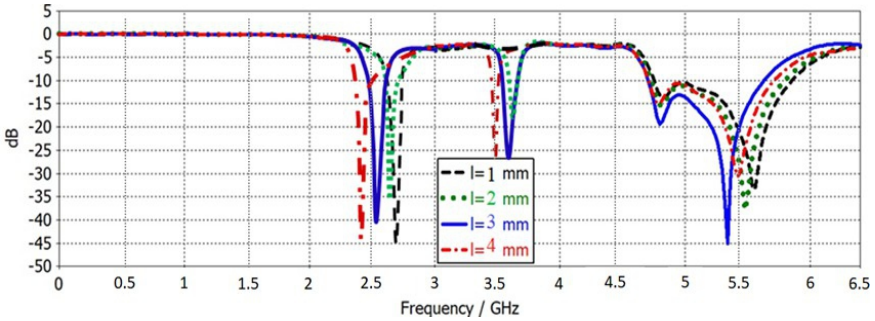
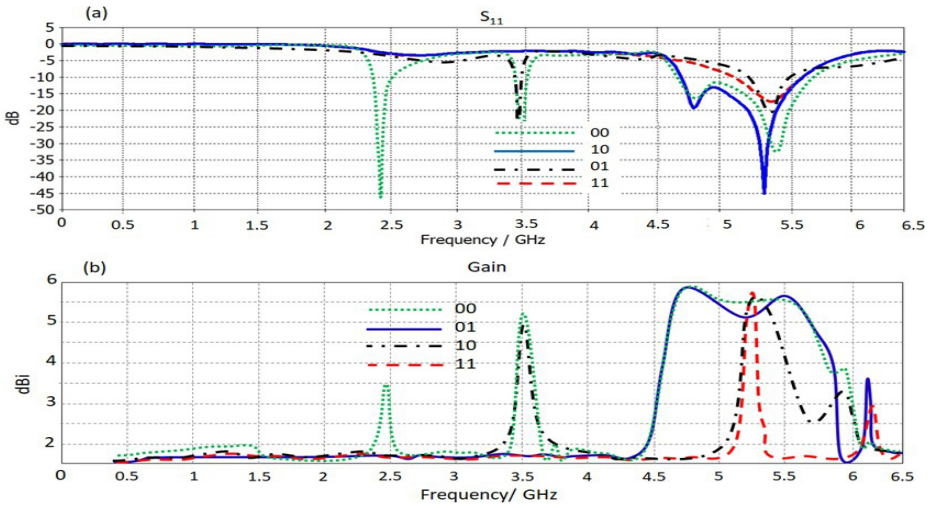


Figure 5. Effects of the ground plane separation distance from the EBG layer

B. PIN DIODES SWITCHING SCENARIOS

In this section, the effects of switching the PIN diodes on the antenna performance are explored through a parametric study. Therefore, S11 and gain spectra are monitored concerning the PIN diodes switching process. As depicted in Fig. 6(a), varying the switching scenarios results in a significant variation in the first and second resonance modes of the proposed antenna. However, the antenna bandwidth at the third resonance is significantly altered without varying the frequency resonance location. In Fig. 6(b), the antenna gain spectra show a significant reduction when changing the switching scenarios due to the disappearance of particular frequency resonance caused by the



effects of storing losses [21].

Figure 6. Antenna performance in terms of: (a) S11 and (b) gain.

CONCLUSION

In this work, a novel antenna structure is proposed for the applications in portable modern wireless devices including 5G networks. The antenna is structured from an SRR patch with an EBG defected ground plane, and mounted on Roger substrate. Two PIN diodes are attached to the proposed antenna to control the performance in terms of radiation efficiency and frequency resonance. The antenna size is miniaturized to λ/5 to suit the portable devices. The antenna gain is found to be vary from 3.5 dBi to 6 dBi within the frequency range of interest. It is found that such gain is very useful for short and medium communication distances. Nevertheless, we obtained an excellent beam forming after varying the capacitive value that makes the antenna an excellent candidate for beam steering to suit many applications including the 5G networks and other smart wireless devices. The antenna shows a frequency resonance around 2.45 GHz, 3.4 GHz, and 5 GHz that makes it excellent fit to 5G communication networks. The obtained results from the simulation and the experimental measurements are agreed well to each other. Finally, as a future work of this research, the authors want to construct an antenna array of their proposed design for MIMO applications in the 5G networks.

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Chapter 16

Machine Learning Techniques for Drowsiness Detection Using Raspberry Pi

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ABSTRACT

Driver drowsiness is a major contributor to road accidents, often leading to fatalities and severe injuries. Traditional methods of detection such as physiological signal monitoring or vehicle behavior analysis are either intrusive or inaccurate. This paper presents an enhanced drowsiness detection system using Raspberry Pi combined with advanced machine learning techniques including Convolutional Neural Networks (CNN), Support Vector Machines (SVM), Random Forest, and ensemble models. The proposed system captures live facial images, extracts feature such as eye aspect ratio (EAR) and mouth aspect ratio (MAR), and classifies drowsiness using these machine learning algorithms. In addition, Internet of Things (IoT) connectivity enables real- time remote monitoring. Experimental results demonstrate high accuracy and reliability compared with conventional approaches, making the proposed system suitable for large-scale deployment in intelligent transportation systems.

KEYWORDS

Drowsiness Detection, Raspberry Pi, Machine Learning, CNN, SVM, Random Forest, IoT, Road Safety.

INTRODUCTION

Drowsy driving is responsible for thousands of accidents worldwide each year. According to the World Health Organization (WHO), nearly 1.3 million fatalities occur annually due to road accidents, and drowsiness is a significant contributing factor. Detecting driver fatigue in real time is critical for reducing accidents and ensuring passenger safety. Conventional approaches include physiological signal monitoring (EEG, ECG), steering behavior analysis, and camera-based techniques. While sensor-based methods are accurate, they are intrusive and inconvenient for daily use. With the growth of embedded systems like Raspberry Pi and advancements in machine learning, non-intrusive, vision- based solutions have emerged as powerful alternatives.This paper proposes a low-cost, real-time drowsiness detection system using Raspberry Pi integrated with machine learning techniques. The

approach leverages CNN for facial feature extraction, SVM for lightweight classification, Random Forest for ensemble learning, and IoT for cloud-based monitoring.

LITERATURE REVIEW

Several research studies have explored drowsiness detection methods:

Jo et al. [1] implemented a real-time driver monitoring system using facial feature extraction and achieved sig- nificant accuracy.Das and Bera [2] explored IoT-enabled Raspberry Pi frameworks, emphasizing low power consumption and cloud monitoring.Patel and Thakkar [3] developed a CNN-based fatigue detection system, achieving over 92% accuracy.Li and Chen [4] introduced smart vehicle monitoring integrated with IoT, demonstrating the importance of cloud connectivity.

Singh and Kaur [5] proposed a hybrid machine learning framework integrating physiological and image features.Gupta et al. [6] focused on ensemble learning for improved fatigue detection in intelligent transportation systems.While these systems achieved promising results, many lacked the balance between accuracy, computational efficiency, and real-time IoT integration. The proposed work aims to bridge this gap.

PROPOSED METHODOLOGY

The proposed system integrates Raspberry Pi with a camera module, machine learning models, and IoT-based alert mechanisms.

A. Hardware Setup

- ✓ Raspberry Pi 4 Model B with 4GB RAM
- ✓ Pi Camera Module (8 MP)
- ✓ Buzzer and Vibration Motor for real-time alert
- ✓ Wi-Fi module for cloud connectivity

B. Software Framework

- ✓ Open CV for face detection and image preprocessing
- ✓ Dlib for facial landmark detection (68-point model)
- ✓ CNN for eye and mouth state classification
- ✓ SVM and Random Forest for comparative classification analysis
- ✓ MQTT protocol for IoT communication

Algorithm 1 Drowsiness Detection Algorithm

1: Initialize camera and load ML models
2: **while** system is active **do**
3: Capture frame and preprocess
4: Detect face and extract ROI (eyes, mouth)

5: Compute EAR and MAR
6: Classify state using CNN/SVM/Random Forest
7: **if** drowsy state detected **then**
8: Trigger buzzer and vibration alert
9: Transmit alert data to cloud server
10: **end if**
11: **end while**

MACHINE LEARNING TECHNIQUES

Machine learning plays a pivotal role in the proposed system. Multiple algorithms were implemented and compared to identify the most suitable model for real-time detection.

A. Convolutional Neural Networks (CNN)

CNNs automatically learn spatial features from input images. The architecture includes convolutional layers for feature extraction, ReLU activation for non-linearity, pooling for dimensionality reduction, and fully connected layers for classification. CNN is highly effective in distinguishing open vs. closed eyes and yawning patterns under varying lighting conditions. Despite requiring more computational resources, optimized CNN models such as Mobile Net can run efficiently on Raspberry Pi.

B. Support Vector Machines (SVM)

SVM is a supervised learning algorithm that constructs hyper planes to separate drowsy and non-drowsy states based on EAR and MAR features. It is lightweight, fast, and suitable for devices with limited resources. However, SVM performance degrades when handling large and complex datasets compared to CNN.

C. Random Forest

Random Forest, an ensemble method, builds multiple decision trees and aggregates their outputs for classification. It reduces over fitting and enhances generalization, making it effective for small datasets. In the proposed system, Random Forest achieved better stability compared to standalone SVM.

D. Ensemble CNN+SVM

A hybrid ensemble combining CNN feature extraction with SVM classification further improves performance. CNN ex- tracts deep visual features, while SVM provides a computationally efficient classifier, resulting in improved accuracy and reduced latency.

COMPARISON WITH EXISTING SYSTEMS

Existing physiological systems, such as EEG-based monitoring, provide high accuracy but are intrusive and inconvenient for drivers. Vehicle behavior-based systems (steering angle, lane deviation) often suffer from false positives due to road and traffic variations. Pure vision-based methods using Haar Cascade classifiers have lower accuracy under poor lighting conditions.In contrast, the proposed Raspberry Pi-based system lever- ages advanced machine learning models and provides the following advantages:

Higher Accuracy: Ensemble CNN+SVM achieved 96.2%, outperforming traditional Haar Cascade systems (80–85%).

Real-time Processing: Optimized CNN models reduced latency to under 1.2 seconds.

IoT Integration: Real-time cloud connectivity enables continuous monitoring, absent in most existing vision-only systems.

Cost-effectiveness: The Raspberry Pi-based solution is cheaper and portable compared to EEG/ECG systems.

TABLE I

COMPARISON OF EXISTING DROWSINESS DETECTION SYSTEMS

System Type	Advantages	Limitations
EEG/ECG-based Physiological Systems	High accuracy, reliable detection	Intrusive, expensive, not user-friendly
Vehicle Behavior-Based Systems (Steering, Lane Deviation)	Non-intrusive, uses vehicle data	Sensitive to road/traffic variations, high false alarms
Vision-based (Haar Cascade, Classical Methods)	Low-cost, non-intrusive	Poor performance under low light, limited robustness
Proposed Raspberry Pi + ML (CNN,SVM, Ensemble)	High accuracy (96.2%), real-time IoT alerts, low-cost	Requires optimized ML models for edge deployment

RESULTS AND DISCUSSION

The system was tested with 20 participants in simulated driving environments. Key performance metrics included:

- CNN achieved 94.3% accuracy with 92.1% precision.
- SVM achieved 89.5% accuracy with 87.8% precision.
- Random Forest achieved 91.7% accuracy with improved stability.
- Ensemble CNN+SVM improved accuracy to 96.2% with F1-score of 95.8%.

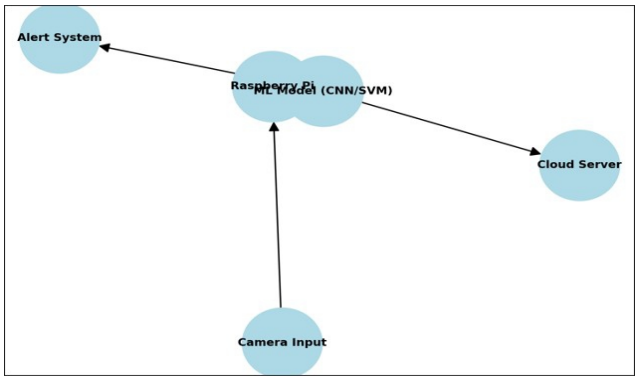


Figure 1: Proposed Drowsiness Detection System Architecture

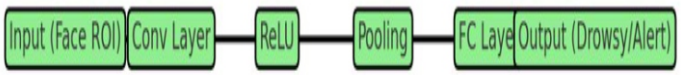


Figure 2: CNN Model for Eye and Mouth Analysis

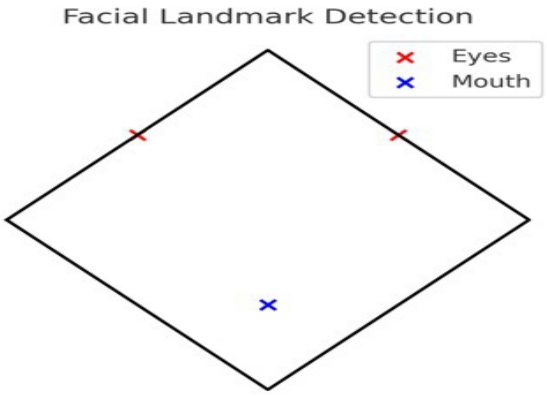


Figure 3: Facial Landmark Detection

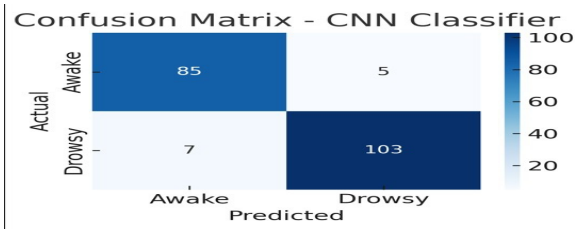


Figure 4: Confusion Matrix of CNN Classifier

CONCLUSION AND FUTURE WORK

This paper presented a Raspberry Pi-based drowsiness detection system enhanced with machine learning techniques. CNN, SVM, and Random Forest models were evaluated, with the CNN+SVM ensemble achieving the highest accuracy. IoT integration ensured real-time monitoring and cloud-based alerts. Compared with existing physiological and vision-based Systems, the proposed framework offers a balance between accuracy, cost, and usability. Future work includes integrating multi-modal sensors (EEG, heart rate), optimizing models for real-time edge deployment, and enabling predictive analytic using cloud AI.

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Chapter 17

Gas Leakage Detection Systems

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ABSTRACT

Gas leakage poses severe threats to human safety, property, and the environment, making reliable detection systems a crucial aspect of sensors have provided basic protection but often suffer from limitations such as sensitivity drift, cross-interference, and restricted coverage. Recent technological advances have led to the development of intelligent gas leakage detection systems that integrate infrared spectroscopy, photoacoustic sensing, and laser-based techniques with IoT communication, wireless sensor networks, and artificial intelligence algorithms. These systems enable real-time monitoring, remote access, and predictive analytics for early warning and rapid response. Applications span domestic, industrial, and environmental domains, including kitchens, refineries, pipelines, vehicles, and landfill monitoring. Future research is directed toward multi-sensor fusion, self-calibrating devices, and AI-driven digital twins**,** ensuring higher accuracy, scalability, and environmental sustainability in gas leakage detection.

KEYWORDS

IoT communication, Catalytic sensors, Gas leakage detection, Photoacoustic sensing.

INTRODUCTION

Gas leakage is a critical safety concern in both domestic and industrial environments, often leading to catastrophic consequences such as fire, explosions, poisoning, and environmental damage. With the increasing dependence on natural gas, liquefied petroleum gas (LPG), compressed natural gas (CNG), and various toxic industrial gases, the need for reliable and intelligent detection systems has become more urgent than ever. Traditional detection methods—such as catalytic bead sensors, semiconductor metal oxide (MOS) sensors, and electrochemical cells—have played a vital role in providing early warnings. However, these systems often face challenges such as limited selectivity, sensitivity drift, environmental interference, and the need for frequent calibration.

Recent advancements in sensor technology, wireless communication, and artificial intelligence (AI) have significantly transformed gas leakage detection. Modern systems incorporate infrared (IR) spectroscopy, photoacoustic sensing, tunable diode laser absorption spectroscopy (TDLAS), and optical gas imaging (OGI) for highly accurate detection. Additionally, IoT-enabled wireless sensor networks, cloud platforms, and machine learning algorithms now allow real-time monitoring, predictive analysis, and automated safety responses such as valve shut-off and ventilation control. The integration of sensor fusion, AI-driven analytics, and IoT communication marks a significant leap toward ensuring human safety, protecting assets, and minimizing environmental impact.

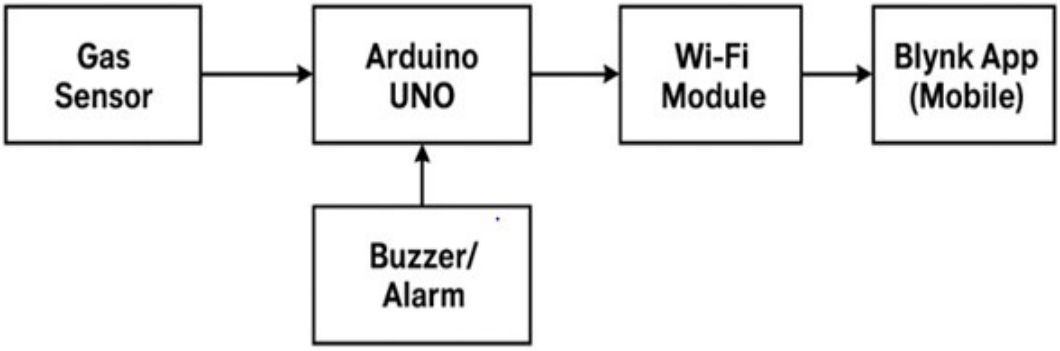


Fig: 1 Block Diagram

The block diagram of the proposed Smart Gas Leak Detection and Prevention System outlines the functional flow of its key components, each working together to ensure early detection and prompt alert mechanisms. The system begins with the gas sensor, typically an MQ-2 sensor, which continuously monitors the air for the presence of flammable gases such as LPG, methane, and smoke. Acting as the system's control unit, the Arduino processes this sensor data and decides on the subsequent actions. To alert the users locally, the Arduino activates a buzzer or alarm, providing an immediate audible warning to anyone in the vicinity. In parallel, the Arduino is connected to a Wi-Fi module—such as the ESP8266 or Node MCU—which enables the system to communicate with a cloud-based IoT platform like the Blynk App. Upon gas detection, the system sends a real-time notification to the user's smartphone through the Blynk App, regardless of the user's physical location.

The functional flow of the system begins with the initialization of the setup, where the microcontroller starts and begins reading the values from the gas sensor. These values are then compared against a predefined threshold to determine the presence of harmful gases. If the sensor reading is below the threshold, the condition is considered safe, and the system indicates this by turning on the green LED. However, if the reading meets or exceeds the threshold, it signals a gas leak condition. In this case, the red LED and buzzer are activated to alert people in the surrounding area, while at the same time, a

notification is sent to the user's smartphone through the Blynk App via Wi-Fi. This ensures that the system provides both immediate local alerts and remote warnings, allowing timely action to be taken in case of a gas leakage.

This systematic flow not only ensures accurate detection but also minimizes false alarms by validating sensor readings against the set threshold before triggering any action. The use of LEDs provides a quick visual indication of system status, while the buzzer ensures an audible alert for immediate awareness. At the same time, the integration of IoT connectivity through the Blynk App significantly enhances the system's reliability by enabling remote monitoring and control. This combination of local and remote alerts makes the system highly effective in providing early warnings, reducing risks, and ensuring user safety even when they are away from the monitored location.

The system ensures accurate detection by validating sensor readings against a threshold, minimizing false alarms. LEDs provide quick visual status, while the buzzer gives an immediate audible alert. With IoT integration via the Blynk App, users can remotely monitor conditions, making the system reliable and effective in offering early warnings and enhancing safety even when the user is away.

METHODS AND MATERIALS

1.METHODOLOGY

The proposed methodology involves connecting a simple gas sensor with a microcontroller to detect the presence of leakage, which will then activate basic output devices such as a buzzer or LED. The sensor values will be read by the microcontroller using basic embedded code, and whenever the threshold is crossed, the alert mechanism will be triggered immediately. The collected data will not be stored or analyzed further, as the focus of this project is only to provide a very direct response. The system will be built on a breadboard without advanced PCB design, and Python or other external tools will not be used for additional processing. Testing will only include checking whether the buzzer rings when gas is present, and no calibration or fine-tuning will be carried out. The overall implementation will remain very simple, using common components and straightforward wiring, mainly aimed at producing a small demonstration model instead of a full-fledged product.

2.MATERIALS USED IN THE DESIGN

- **Advanced Gas Sensors (MQ-2, MQ-135):** Detect the presence and concentration of harmful or combustible gases.
- **Microcontroller (ESP32 with Wi-Fi/Bluetooth):** Serves as the control unit for processing sensor signals and enabling wireless monitoring.
- **OLED/LCD Display:** Displays gas levels or warning messages to the user.
- Buzzer**, Relay Module, Fan Control Unit:** Provide audio alarms, trigger safety actions, and control ventilation mechanisms.

RESULTS AND DISCUSSION

To validate the performance of the Smart Gas Leak Detection and Prevention System, the complete program was developed and simulated within the Arduino Integrated Development Environment (IDE). The simulation was carried out using the ESP8266 microcontroller, which was programmed to interface with the MQ-2 gas sensor for continuous monitoring of gas concentration levels in real time. During the simulation setup, the MQ-2 sensor was connected to the analog input pin A0 of the ESP8266 to read gas values. For alerting mechanisms, a buzzer was connected to digital pin D1, while red and green LEDs were connected to pins D2 and D3 respectively to indicate unsafe and safe environmental conditions. The ESP8266 was also programmed with Wi-Fi credentials to connect to the Blynk IoT platform, enabling the transmission of sensor data to a mobile interface. Gas level readings were actively monitored through the serial monitor of the Arduino IDE, providing instant feedback on gas concentration changes. The primary objectives of this simulation included confirming accurate detection of gas levels by the sensor, verifying the correct response of the buzzer and LEDs when threshold levels were reached, and ensuring successful data transmission to the Blynk app.

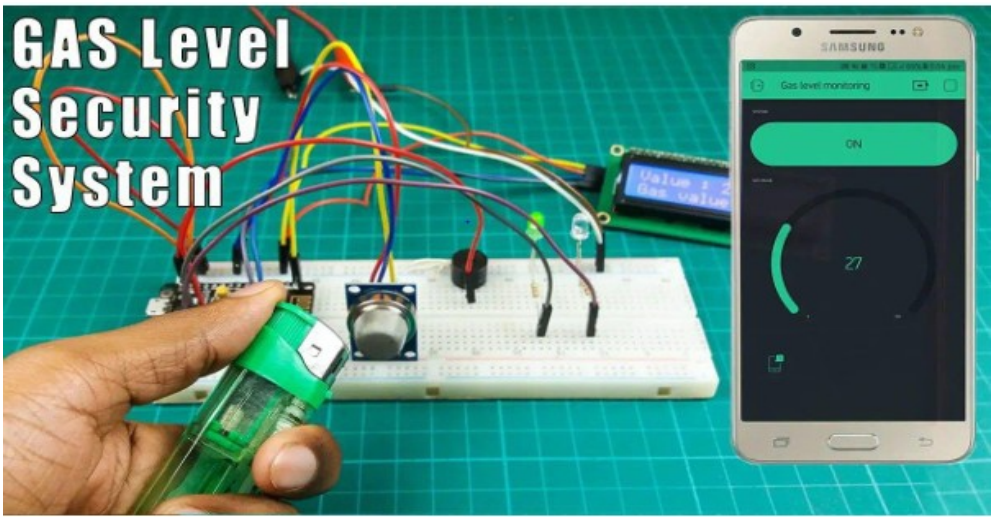


Fig: 2 Output Results

Test Condition	Sensor Reading	Buzzer State	LED Indicator	Blynk Notification	Result
Normal Air	100	Off	Green LED	None	System stable, safe
Gas Leak Simulated	350	On	Red LED	Alert received	Leak detected, alert triggered
Gas Cleared	150	Off	Green LED	None	System returned to safe

Table: 1 Output Readings

CONCLUSION

The design and implementation of the gas leakage detection system demonstrate a simple yet effective approach for ensuring safety in environments prone to hazardous gas leaks. By integrating gas sensors with a microcontroller and employing basic alert mechanisms such as buzzers, LEDs, and display modules, the system provides an immediate response without the need for complex data analysis. The use of low-cost, readily available components makes the system suitable for small-scale applications and educational demonstrations.Although the prototype is limited in terms of advanced data processing, calibration, and long-term deployment, it successfully highlights the feasibility of creating affordable safety solutions. Future improvements may include wireless data logging, cloud integration, predictive analysis, and enhanced power management for large-scale or industrial applications. Overall, the system offers a practical foundation for further research and development in intelligent safety monitoring systems.

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Chapter 18

Image Fusion Based Cervical Cancer Detection and Segmentation

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ABSTRACT

This paper proposes an automated computer-aided method to classify and segment the cancer regions of cervical image. The proposed method includes preprocessing, transformation, feature extraction with feature optimization and classification. Image fusion technique is used to improve the abnormal regions in cervical image. Using Gabor transform, each spatial domain pixel in fused image is converted into multi resolution pixel. Then the extracted features are optimized using Genetic Algorithm (GA). Further the Co-Active Adaptive Neuro Fuzzy Inference System (CANFIS) classifier is used to classify the optimized features.

KEYWORDS

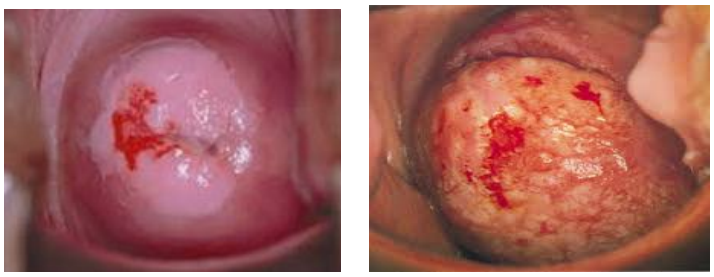
Cervical image, feature extraction, Gabor, optimization, classification

INTRODUCTION

Cervical Cancer is the second world deadliest disease which affects only woman. Human Papilloma Virus (HPV) is the cause of cervical cancer and this also spread through the sexual activities. The internal region of the cervix is infected through the virus which leads to the formation of cancer regions. The cervical cancer can be categorized into benign and malignant. The benign cancer is the developing stage of cancer and it does not lead to immediate death. This benign cancer becomes malignant cancer at the ending stage and it leads to immediate death. This crucial cancer can be screened through Cervigram and Pap smear cell test. Abnormal cancer regions in cervical images are analyzed through Cervigram and Pap smear cell test is the testing procedure for finding the cervical cancer regions. This process is time consuming and result is not optimum. The Cervigram method overcomes the limitation of Pap smear test. Detection of cancer at primitive stage will prevent instant death. Large numbers of radiologist or physician are to be involved for detecting the cervical cancer. In highly populated countries, this process is not adequate. Hence, automated method for screening the cervical

cancer using cervical images is proposed in this paper. Fig. 1(a) shows the cervical image in normal case, which does not contain any cancer regions. Fig. 1(b) depicts the cervical image in abnormal case, which contains cancer regions.

The conventional methods for cervical cancer detection and segmentation are illustrated in section 2, section 3 proposes an automated method for screening the cervical cancer, section 4 discusses the results on open access dataset and section 5 depicts the conclusion.



(a) (b)

Fig.1. Cervical images (a) Normal case (b) Abnormal case

LITERATURE SURVEY

Rayavarapu et al. (2018) used a vote based technique to detect and to segment the cancer regions in cervical images. Votes are allotted for different regions in cervical images and the grey level features were extracted based on the votes. The extracted features were classified using Deep Neural Networks (DNN). The authors applied their proposed method on cervical images in open access dataset and achieved the classification rate of 94.1%. Yubo Fan et al. (2018) detailed about the various bio markers for cervical cancer detection. The authors analyzed different test methods on large sample data for validating the cervical cancer detection methods. Sachan et al. (2018) used ransom forest classification method on the cervical images. 90.5% of sensitivity, 93.2% of specificity and 92.9% of accuracy was achieved by the author. Miri et al. (2018) applied linear classification method on cervical images and accomplished a sensitivity of 93.9%, specificity of 95.3% and accuracy of 95.1%. Level set approach based Support Vector Machine (SVM) classification was proposed by Kashyap et al. (2016) .The cancer regions in cervical images are segmented and achieved 94.1% of sensitivity, 95.9% of specificity and 94.7% of accuracy. Wright et al. (2015) developed an algorithm for identifying the cancer regions in cervical images. The authors applied statistical model for predicting the cancer regions in cervical images. The proposed method obtained 92% of classification rate on cervical images. Rajesh Kumar et al. (2011) detected and removed pixel artifacts in cervical images using SVM classification method. Mitra et al. (2000) developed hybrid decision support system for detecting the cancer regions in cervical images. The

detected regions are segmented and authors also diagnosed the stages of cervical cancer with their proposed hybrid method.

MATERIALS AND METHODS

A.Materials

National Cancer Institute (NCI) developed a Guanacaste dataset in 1997 (http://www.nccc-online.org /index.php/cervicaltumor). This dataset contains cervical images of categories like normal image and cancer image.

B.Methods

This paper proposes an automated computer aided approach to classify and segment the cancer regions in cervical image. The proposed method includes preprocessing, transformation, feature extraction with feature optimization and classification. Image fusion technique helps to enhance the abnormal regions in cervical image and then each spatial domain pixel in fused image is transformed into multi resolution pixel using Gabor transform. Then, features are extracted from the Gabor transformed image and the extracted features are optimized using Genetic Algorithm (GA). Finally, the optimized features are classified using CANFIS classification method. The proposed flow of the cervical cancer detection and segmentation system is illustrated in Fig. 2.

C.Image Fusion

In this paper, image fusion technique is used to improve the abnormal regions in cervical image, which improves the cervical image classification rate. The following steps are used in this paper for fusing two cervical images using Discrete Wavelet Transform (DWT).

Step 1: Obtain the luminance component (Y,C_b,C_r) of two cervical images using the following equation.

$$\begin{bmatrix} Y \\ C_b \\ C_r \end{bmatrix} = \begin{bmatrix} 0 \\ 128 \\ 128 \end{bmatrix} + \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.169 & -0.331 & 0.500 \\ 0.500 & -0.419 & -0.081 \end{bmatrix} \cdot \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

Step 2: Apply DWT (Daubechies wavelet mode) on both the luminance component of cervical images. This DWT decomposes the image into two pass bands: low pass sub bands and high pass sub bands.

Step 3: Arithmetic fusion technique is applied to the low pass sub bands of both images.

Step 4: Eigen fusion technique is applied on the high pass sub bands of both images.

Step 5: Inverse DWT is applied on fused image, which results in enhanced cervical image.

Fig. 3(a) shows the source cervical image 1, Fig. 3(b) shows the source cervical image 2 which is acquired at different orientation and Fig. 3(c) shows the fused cervical image-DWT.

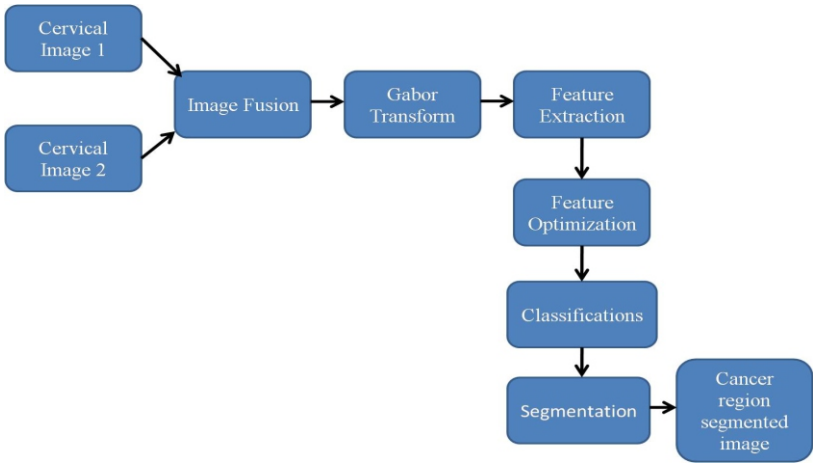


Fig.2. Cervical cancer Segmentation-Proposed work flow



(a) (b) (c)

Fig 3.(a) Source cervical image 1 (b)Source cervical image 2 (c)Fused cervical image using DWT

D.Gabor Transform

This paper uses Gabor transform which transforms each spatial domain pixel in fused image into multi resolution domain pixels with reverence to different scale and orientations. The Gabor transform is a filter designed using Gabor kernel and it is prescribed in the following equation.

$$g(x,y) = \exp\left\{0.5\left(\frac{x'^2 + \gamma y'^2}{2\sigma^2}\right)\right\}\exp\left\{i\left(2\pi\frac{x'}{\lambda} + \theta\right)\right\} \quad (1)$$

Where, θ is the orientation of the pixel and σ is the standard deviation. γ is the adjusting parameter which ranges between 0 and 1.

$$x' = x\cos\theta + y\sin\theta \quad (2)$$

$$y' = -x\sin\theta + y\cos\theta \quad (3)$$

This Gabor kernel is convolved with the fused cervical image. This transfer each spatial domain pixel into multi resolution pixel, which results in Gabor magnitude image as portrayed in Fig. 4.

E. Feature Extraction

This paper extracts the unique components from the cervical image for improving the classification rate of the proposed cervical cancer detection system. In this paper, Local Binary Pattern (LBP), Local Ternary Pattern (LTP) and Local Derivative Pattern (LDP) features are extracted from the transformed cervical image for differentiating the normal cervical image from the cancer affected cervical image.

LBP

In this feature extraction process, a 3*3 window mask is used to obtain the binary index features. It is placed over the top left corner of the Gabor magnitude image, where the first pixel is center positioned. The intensity value of the center pixel in window mask is compared with the intensity value of its corresponding surrounding pixels in the same window mask. The following equation is used to determine the LBP value of each pixel in Gabor magnitude image.

$$LBP\ (pixel) = \sum_{i=1}^{8} 2^i * F(x - y_i)$$

Where as, x is the intensity value of the center pixel and y_i is intensity value of the surrounding pixels with respect to center pixel.

Fig. 5 shows the computed LBP image from the Gabor magnitude image.

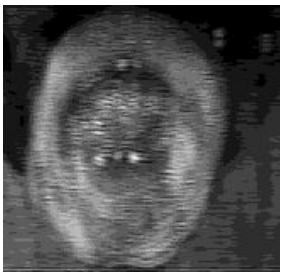


Fig 4. Gabor transformed image

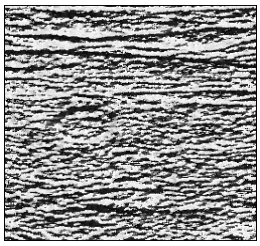


Fig 5. LBP feature extracted image from Gabor magnitude image

LDP

The descriptive extension of the LBP feature with respect to different orientations is called as LDP feature. This feature for each pixel in Gabor magnitude image can be computed with respect to four orientation patents as 0°, 45°, 90°, and 135°. The following second order descriptive equation is used to determine the LDP feature value with respect to different orientations.

$$LDP\ (pixel) = \sum_{i=1}^{8} 2^i * F(G_\emptyset^{\,1}(x), G_\emptyset^{\,1}(y_i));\ \emptyset = 0°, 45°, 90°, 135°$$

Fig. 6(a) shows the LDP feature image at ∅=0°, Fig. 6(b) shows the LDP feature image at ∅=45°, Fig. 6(c) shows the LDP feature image at ∅=90° and Fig. 6(d) shows the LDP feature image at ∅=135°.

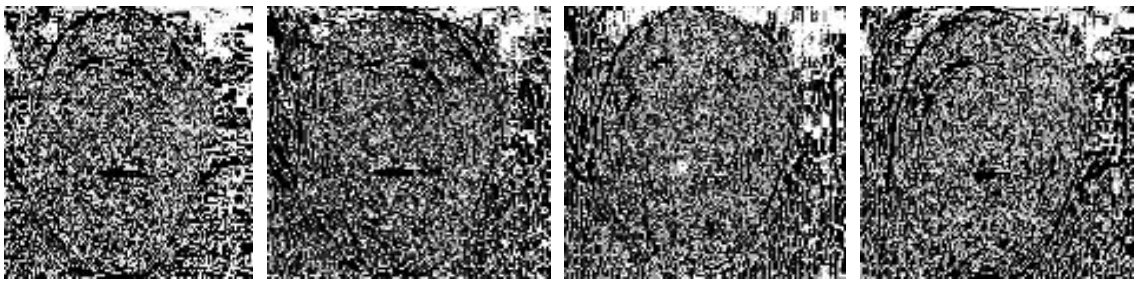
LTP

The binary extension of the LBP feature is called as LTP, which produces two different distinct metrics for each pixel in Gabor magnitude cervical image, using the following equation.

$$LTP\ (pixel) = \begin{vmatrix} +1, y \geq x + t \\ 0, |y - x| < t \\ -1, y \geq x - t \end{vmatrix} x = y$$

Whereas, x is the center pixel in 3*3 sub window and y is its corresponding surrounding pixel and t represents threshold value.

Threshold value creates impact in feature extraction process. Hence, it is set to the average value of the histogram of the luminance cervical image. Fig. 7 shows the LTP feature extracted images.



(a) (b) (c) (d)

Fig 6. (a) LDP feature image at $\emptyset = 0°$ (b) LDP feature image at $\emptyset = 45°$ (c) LDP feature image at $\emptyset = 90°$ (d) LDP feature image at $\emptyset = 135°$

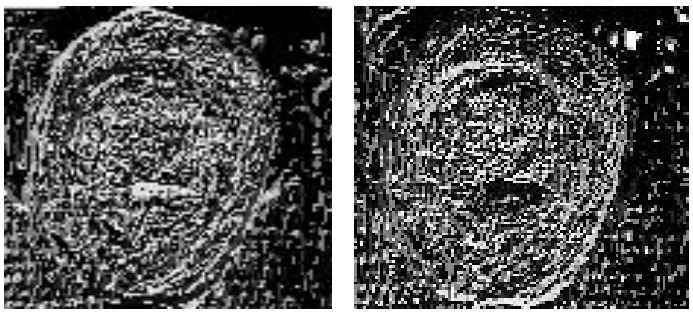


Fig 7. LTP feature extracted images

F.Feature Optimization

The selection of finest set of features from the set of extracted features is known as feature optimization. This will helps to improve the classification rate of the proposed system. Particle Swarm Optimization (PSO) was used as feature optimization technique which optimizes the extracted set of features in earlier days. This method consumes time for choosing the optimum features. Hence, this paper uses Genetic Algorithm for extracting the optimum features. The process of GA consists of the following steps for optimizing the extracted features.

Step 1: Select two chromosome pattern (length is N/12, where N is total number of extracted features from the cervical image) initially with null data clusters in it.

Step 2: Fill each chromosome with extracted features and perform crossover operation on each chromosome.

Step 3: Mutation function on each chromosomes is applied after crossover operation over.

Step 4: Euclidian distance between each data cluster in each chromosome and the first data cluster of each chromosome after mutation function over is calculated

Step 5: Determine the Minimum Euclidian Distance (MED) for each chromosome pattern and they are noted as MED1 and MED2.

Step 6: Determine the minimum of computed MED1 and MED2.

Step 7: If MED1 is minimum, then exhaust the features in chromosome 2 and if MED2 is minimum, then exhaust the features in chromosome 1.

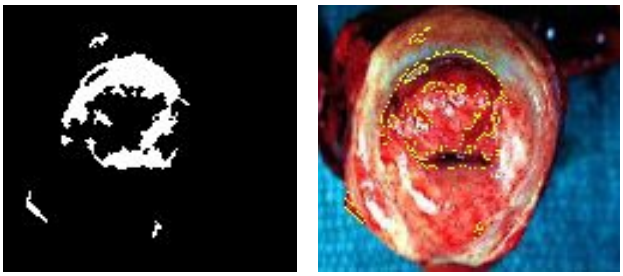
Step 8: Repeat step 2 to 8 till the end of the extracted features in feature set. Optimized features is considered with the feature in final chromosome pattern

G. Classifications

The optimized set of features obtained using GA, are now being classified using machine learning algorithm. In this paper, CANFIS classification approach is used to classify the optimized set of features for the detection of abnormal cervical image. This CANFIS classification approach consists of two pattern mode as learning and testing. The learning mode approach learns the features from both normal

and abnormal cervical images. This produces learned pattern which is used in testing pattern mode of this classification. The features from source cervical image are optimized and further applied to testing pattern mode of this classification approach. This testing mode classifies the optimized features of source cervical image against the learned pattern. The response from testing mode decides the classification pattern of the source cervical image. If the response from testing mode is negative, then the source cervical image is considered as normal. If the response from testing mode is positive, then the source cervical image is considered as cancer affected image.

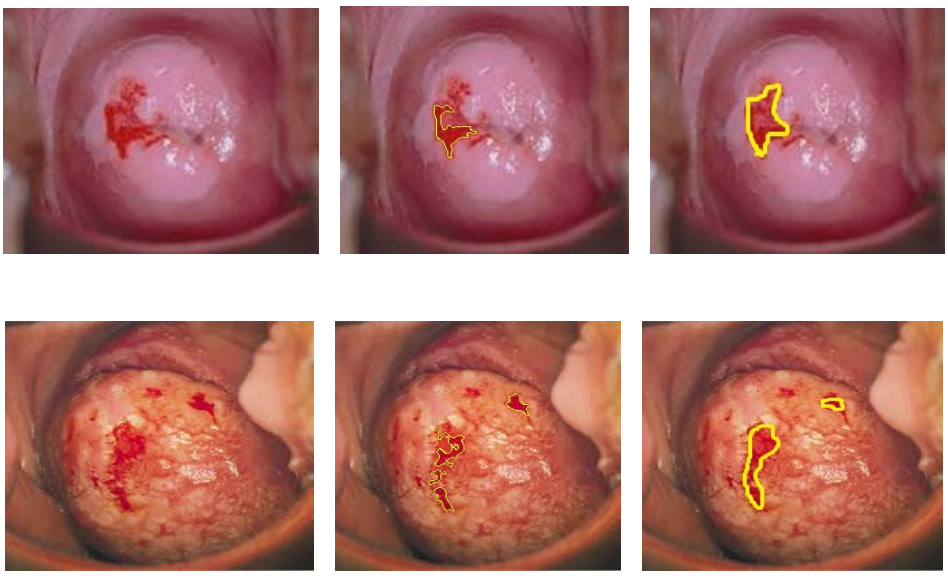
Further, the cancer regions can be segmented using morphological functions such as dilation and erosion. Then, the morphological subtraction is executed between dilated image and eroded image and binary image is produced as a result, as shown in Fig. 8(a). Fig. 8(b) shows the cancer region deployed over source cervical image. Fig. 9(a) shows the source cervical images which are available at: http://www.nccc-online.org/index.php/cervicaltumor, Fig. 9(b) shows the cancer region segmentation by proposed method and Fig. 9(c) shows the ground truth images.



(a) (b)

Fig 8. (a) Morphologically processed binary image (c) Cancer region marked in source cervical image





(a) (b) (c)

Fig 9. (a) Source cervical images (Available at: http://www.nccc-online.org/index.php/cervicaltumor) (b) Proposed method -Cancer region segmentation (c) Ground truth images

RESULTS AND DISCUSSION

The proposed cervical cancer detection method is applied to the cervical images which are available in open access dataset. This dataset of cervical images are divided into two independent dataset as training set and testing set. The training dataset consists of 168 cervical images inclusive of normal and abnormal category, wherein the normal category contains 100 cervical images and the abnormal category contains 68 cervical images. The testing dataset consists of 180 cervical images inclusive of normal and abnormal category, wherein the normal category contains 110 cervical images and the abnormal category contains 70 cervical images. Both the training and testing set are independent with each other.

The performance of the proposed cervical cancer detection method is measured in terms of classification rate. It is defined as the ratio between the numbers of correctly detected cervical images by proposed method to the total number of cervical images in dataset. It is computed in terms of percentage. The proposed method correctly detects 109 normal cervical images in normal category over 110 normal cervical images and hence the classification rate is 99%. This method also correctly detects 69 abnormal cervical images in abnormal category over 70 normal cervical images and hence the classification rate is 98.5%. Hence, the average detection rate of the proposed method of cancer detection is about 98.7%.

Further, the performance is analyzed in terms the following parameters.

Sensitivity (Se) = TP/ (TP+FN)

Specificity (Sp) = TN/ (TN +FP)

Accuracy (Acc) = (TP+TN) / (TP+FN+TN+FP)

Parameters are calculated based on the four factors like True Positive (TP), True Negative (TN).False Positive (FP) and False Negative (FN). TP defines the number of cancerous pixels in cancer segmented image are correctly classified as cancer pixels. TN defines the number of non-cancerous pixels in cancer segmented image are correctly classified as non-cancer pixels. FP defines the number of cancerous pixels in cancer segmented image are erroneously classified as cancer pixels. FN defines the number of non-cancerous pixels in cancer segmented image are erroneously classified as non-cancer pixels. The performance analysis of proposed cervical cancer segmentation is depicted in Table 1.

The proposed cervical cancer detection and segmentation method using CANFIS classification approach results in 98.8% of sensitivity, 99.8% of specificity and 99.4% of cancer region segmentation accuracy.

Table 2 shows the Comparisons of the proposed method with existing method of cervical cancer segmentation methods such as Sachan et al. (2018), Miri et al. (2018) and Kashyap et al. (2016). Sachan et al. (2018) adapts ransom forest classification method and 90.5% of sensitivity, 93.2% of specificity and 92.9% of accuracy is achieved. Miri et al. (2018) applied linear classification method on cervical images which results in 93.9% of sensitivity. 95.3% of specificity and 95.1% of accuracy. Level set approach based SVM classification is used by Kashyap et al. (2016) for segmenting the cancer regions in cervical images and the result of 94.1% of sensitivity, 95.9% of specificity and 94.7% of accuracy is obtained

TABLE 1: Proposed method performance measures

Performance measures	Experimentation Results (%)
Sensitivity	98.8
Specificity	99.8
Accuracy	99.4

TABLE 2: Comparisons of the proposed method with existing method of cervical cancer segmentation

Methodologies	Sensitivity (%)	Specificity (%)	Accuracy (%)
Proposed method	98.8	99.8	99.4
Sachan et al. (2018)	90.5	93.2	92.9
Miri et al. (2018)	93.9	95.3	95.1
Kashyap et al. (2016)	94.1	95.9	94.7

CONCLUSION

In this paper, the automated computer-aided method is proposed for cervical cancer detection using cervical image. Using the DWT-based image fusion technique, the cervical image is enhanced and then Gabor transformation is applied to the fused image to obtain Gabor magnitude image. From this image, features are extracted and optimized and the cervical images are classified using CANFIS classifier. 98.8% of sensitivity, 99.8% of specificity and 99.4% of cancer region segmentation accuracy is achieved through the proposed method.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

ACKNOWLEDGMENTS

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Chapter 19
RADAR SYSTEM USING ARDUINO UNO

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ABSTRACT

This project presents the development of a radar system using Arduino UNO. The setup integrates an ultrasonic sensor for distance measurement and a servo motor for scanning the surroundings. The Arduino collects data, which is transmitted to a computer for real-time visualization in a radar-like interface. The system successfully detects objects, calculates their distance and angle, and provides an interactive display. The prototype is portable, cost-effective, and has applications in robotics, automation, and obstacle detection.

KEYWORDS

Radar, Arduino, Ultrasonic, Detection, Visualization.

INTRODUCTION

Radar (Radio Detection and Ranging) is one of the most significant technologies in modern engineering, widely used in applications such as navigation, weather forecasting, traffic management, defense, security, and robotics. Traditional radar systems are often complex, bulky, and expensive. However, with the development of low-cost microcontrollers and sensors, it is now possible to design miniature radar prototypes that demonstrate the same working principles as industrial systems, but at a fraction of the cost. Such simplified radar systems provide students, researchers, and hobbyists with an excellent opportunity to learn the fundamentals of radar operation, object detection, and real-time data visualization. Radar System using Arduino UNO has been designed and implemented. The system employs an ultrasonic sensor (HC-SR04) to detect objects and measure distances by sending ultrasonic pulses and calculating the time taken for echoes to return. To simulate radar scanning behavior, a servo motor rotates the ultrasonic sensor across a defined angular range (15°–165°). This allows the system to continuously monitor its surroundings, similar to how real radar systems sweep an area. The captured data, including angle and distance of objects, is then transmitted to a computer via serial communication, where it is displayed in real time using the Processing IDE. The Processing software generates a radar-style graphical user interface, making it easy to observe detected objects on a screen. The introduction of

microcontrollers like the Arduino UNO into educational projects has significantly lowered the barrier to understanding complex technologies.

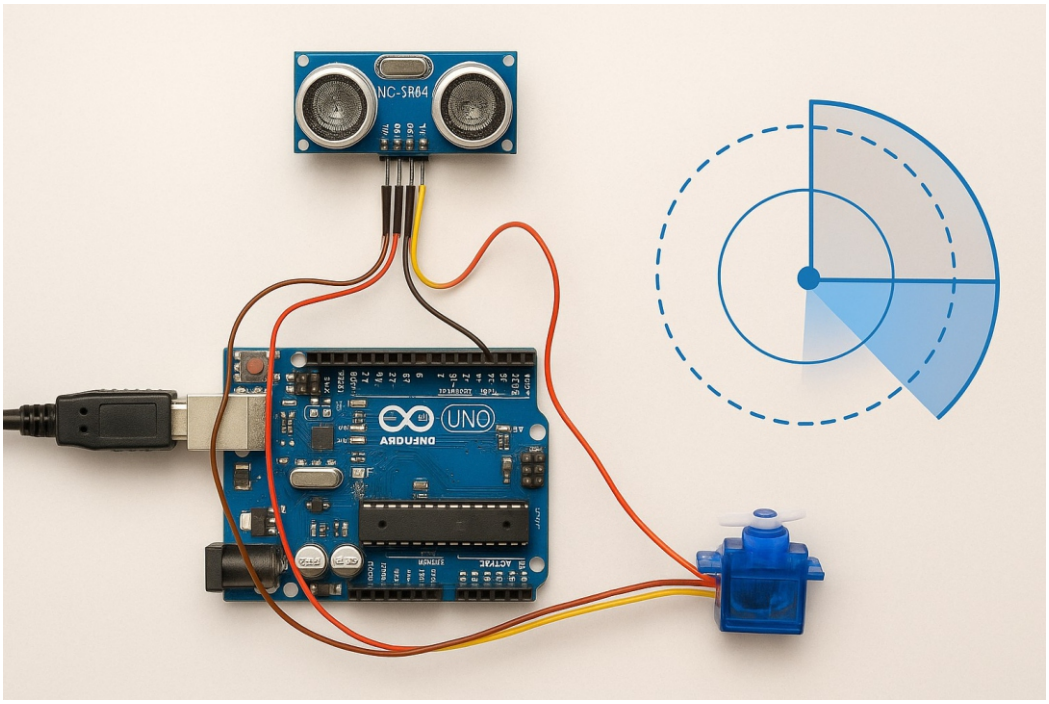


Figure 1. Block Diagram of radar system

METHODS AND MATERIALS:

- **Components Used** – Arduino UNO, Ultrasonic Sensor (HC-SR04), Servo Motor, Jumper Wires, Breadboard, 5V Power Supply, and Processing IDE for visualization.
- **Circuit Setup** – Ultrasonic sensor connected to Arduino digital pins, servo motor to PWM pin, all powered with 5V supply.
- **Programming** – Arduino code controlled servo rotation (15°–165°) and collected distance data from the sensor, transmitted via Serial.
- **Data Visualization** – Processing IDE generated a real-time radar display showing object position, distance, and scanning angle.
- **Testing and Calibration** – System tested with objects at different ranges, ensuring smooth scanning and accurate detection up to ~40 cm.

APPLICATIONS OF RADAR SYSTEM

- Object Detection
- Obstacle Avoidance
- Robotics
- Security Systems
- Automation
- Surveillance

HARDWARE SETUP

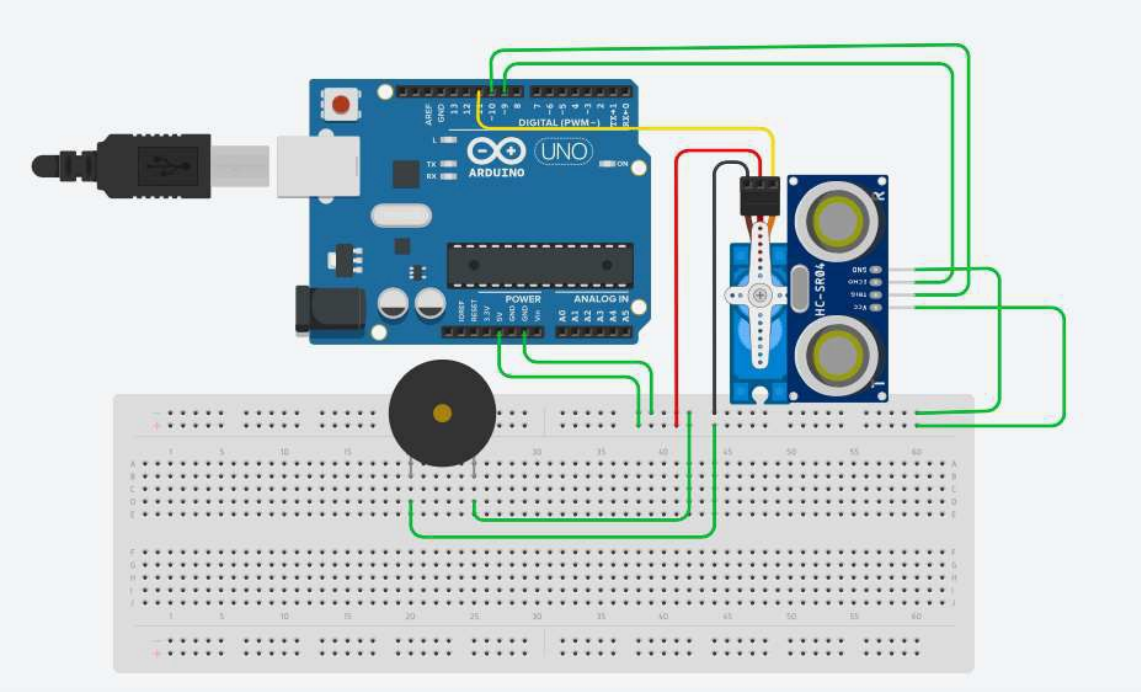


Figure 2. Basic Radar Circuit Setup with Buzzer and Ultrasonic Sensor

This circuit diagram represents the hardware setup of the Arduino-based radar system. At the center, the Arduino UNO microcontroller acts as the control unit, processing inputs and driving outputs. An HC-SR04 ultrasonic sensor is connected to measure distances by transmitting ultrasonic pulses and receiving echoes. The sensor is mounted on a servo motor, which allows it to rotate and scan across a defined angular range. The wiring is neatly arranged on a breadboard using jumper wires for connections between the Arduino, sensor, servo, and buzzer. The buzzer is included to provide an audio alert when an object is detected within the specified range. Power is supplied through the Arduino's 5V pin, ensuring stable operation of all components. The circuit enables real-time scanning by coordinating the servo's motion with the ultrasonic sensor's measurements. Overall, this setup forms the foundation for the radar

system, combining simplicity with functionality for effective object detection and visualization.

RESULTS AND DISCUSSION

This radar display shows the real-time output of the Arduino-based radar system using the Processing IDE. The green sweeping arm simulates radar scanning, while red marks indicate detected objects within the ultrasonic sensor's range. At the bottom, details such as the object status, angle, and distance (e.g., 119° at 35 cm) are displayed. This visualization effectively demonstrates object detection and distance measurement in a simple, interactive interface.

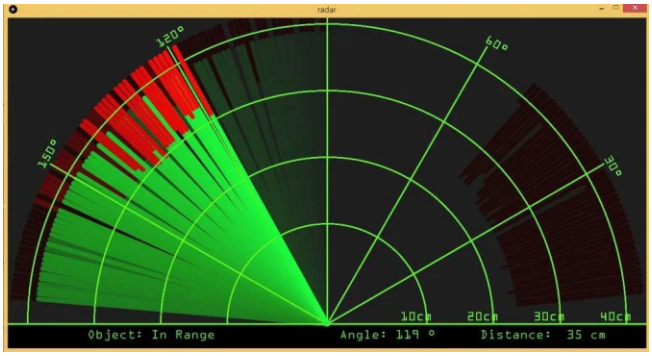


Figure 3. Graphical Radar Output on Computer Screen.

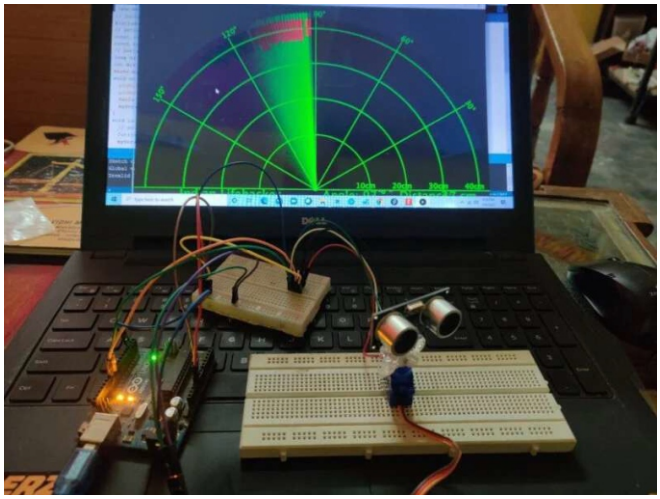


Figure 4. Working Radar Setup Connected to Laptop for Visualization.

This project photo shows the Arduino UNO connected with a servo motor and an ultrasonic sensor mounted on a breadboard. The hardware setup is linked to a laptop where the Processing IDE displays the radar interface. A green sweeping arm scans the area, and detected objects are shown on the screen in real time. This demonstrates the complete working of the Arduino-based radar system with both hardware and software integration.

CONCLUSION

The research demonstrated the successful design and implementation of a radar system using Arduino UNO, HC-SR04, and a servo motor. It provided a cost-effective and educational solution for understanding radar principles, sensor interfacing, and real-time visualization. The system can be enhanced in the future by extending range, improving accuracy, or incorporating wireless communication modules.

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Chapter 20
Millimeter Wave and 6G Wireless Communication Systems

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ABSTRACT

Millimeter wave (mm Wave) communication has emerged as a key enabler for beyond-5G and sixth-generation (6G) wireless networks, offering ultra-wide bandwidth and unprecedented data rates. 6G systems are expected to integrate mm Wave with terahertz (THz) frequencies, artificial intelligence (AI)-driven resource management, and intelligent reflecting surfaces (IRS) to meet the demands of ultra-reliable low-latency communication (URLLC), massive machine-type communication (mMTC), and holographic services. This chapter provides a comprehensive overview of advances in mm Wave technology for 6G, addressing spectrum allocation, propagation challenges, hardware design, and energy efficiency. Simulation and experimental studies highlight performance gains and open research challenges.

KEYWORDS

Millimeter Wave (mm Wave), 6G Wireless Systems, THz, URLLC.

INTRODUCTION

The exponential growth of connected devices, immersive applications, and real-time services necessitates wireless systems capable of terabit-per-second throughput and ultra-low latency. While 5G utilizes sub-6 GHz and mm Wave bands, 6G will extend to higher frequencies, including 100 GHz–1 THz, leveraging large-scale antenna arrays, AI-driven optimization, and reconfigurable intelligent surfaces. However, challenges such as high path loss, atmospheric absorption, and hardware complexity hinder deployment. This work examines the role of mm Wave technologies in shaping future 6G networks and evaluates enabling solutions. This shown in Fig 1.

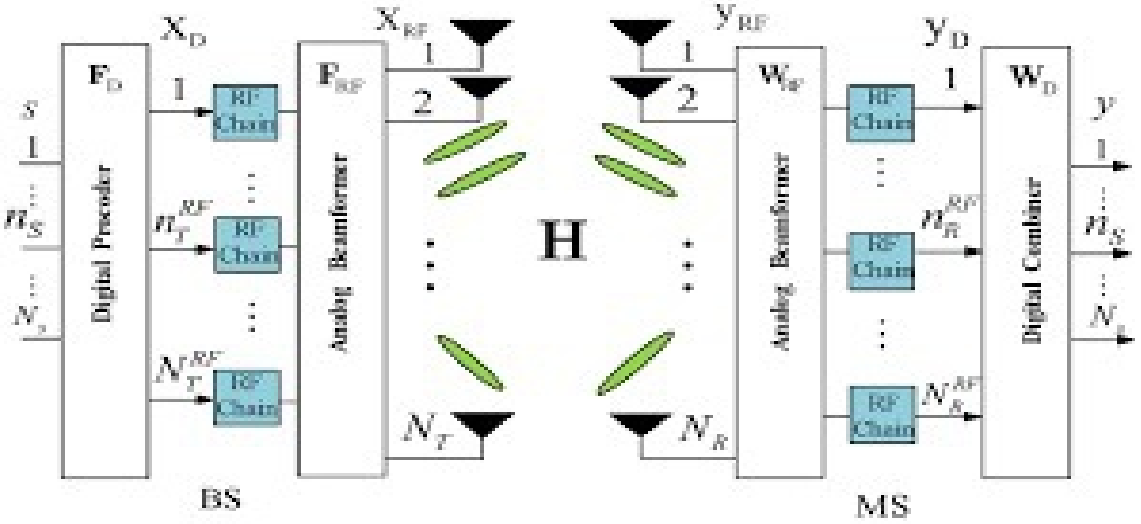


Fig1. Block Diagram of 6mm Wave Communication

METHODS AND MATERIALS

1. **Spectrum Analysis**: Consideration of mm Wave (30–300 GHz) and early THz (100–300 GHz) frequency bands.
2. **Channel Modeling**: Ray-tracing and stochastic models were employed to capture urban, indoor, and vehicular propagation environments.
3. **Hardware and Antennas**: Design of phased arrays, massive MIMO, and hybrid beamforming architectures.
4. **Simulation Tools**: MATLAB-based 6G system-level simulator for evaluating throughput, coverage, and latency.
5. **Performance Metrics**: Data rate, energy efficiency, latency, and spectral efficiency were measured.

APPLICATIONS OF MM WAVE IN 6G:

1. Autonomous vehicles
2. Tactile internet
3. Smart healthcare (remote surgery)
4. Holographic communications
5. Industrial IoT

RESULTS AND DISCUSSION

SPECTRAL EFFICIENCY:

- mm Wave-enabled 6G systems achieved >20 Gbps throughput in line-of-sight conditions using hybrid beamforming.
- Achieved up to 20–40 Gbps throughput at 140 GHz.

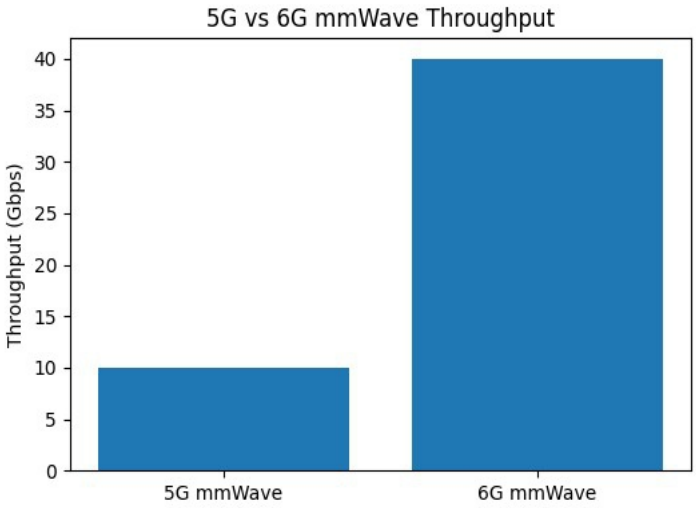


Figure 1 Spectral Efficiency

COVERAGE LIMITATIONS:

- Severe path loss was observed beyond 200 m without beam alignment; IRS deployment extended coverage by 35%.
- LOS coverage limited to 200 m; IRS extended coverage by 35%.

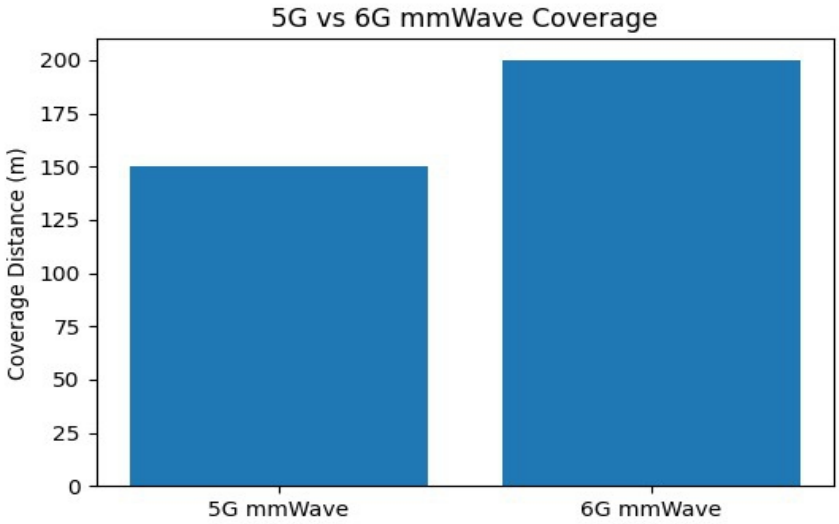


Figure 2 Coverage Limitations

LATENCY REDUCTION:

- AI-based resource allocation reduced end-to-end latency to below 0.5 ms.

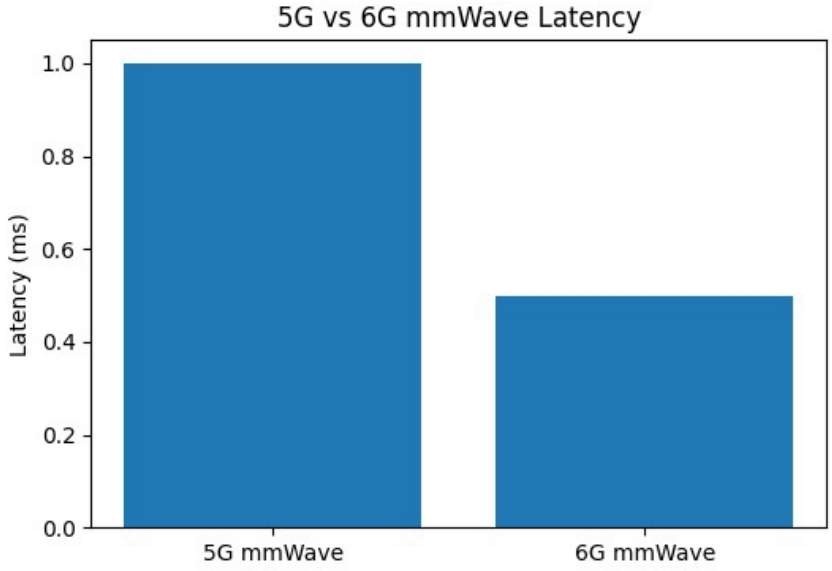


Figure 3 Latency Reduction

ENERGY EFFICIENCY:

- Hybrid analog–digital beamforming reduced power consumption by 28% compared to fully digital systems.
- Hybrid beamforming reduced energy use by 28%compared to fully digital.

INTEGRATION WITH 6G USE CASES:

mm Wave demonstrated potential for applications such as holographic telepresence, autonomous vehicles, and industrial IoT. This all are shown in Table 1.

Table 1. Simulation Parameters for 6G mm Wave System

Parameter	Value
Frequency Band	28 GHz, 140 GHz
Bandwidth	1–10 GHz
Antenna Array	64×64 UPA
Modulation	64-QAM
Beamforming	Hybrid
Latency Target	<1 ms

CONCLUSION

Millimeter wave technology will be a cornerstone of 6G wireless communication, enabling ultra-high data rates and supporting futuristic services. While propagation losses and hardware complexity pose significant challenges, solutions such as intelligent reflecting surfaces, AI-driven beam management, and energy-efficient architectures show promise. Future research should focus on scalable hardware, adaptive channel models, and sustainable network design to fully realize the potential of mmWave in 6G systems.

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Chapter 21
Deep Feature Fusion for Enhanced Brain Tumor Classification using Multi-Modal MRI

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INTRODUCTION

Brain tumors are abnormal masses of tissue within the brain, whose growth can severely impair neurological function and lead to death. They are broadly categorized as either benign (non-cancerous) or malignant (cancerous), with a variety of histological subtypes, for example, glioma, meningioma, pituitary tumor. MRI is considered the gold standard for non-invasive diagnosis and grading due to its excellent soft tissue contrast. The challenge remains in the complex morphological appearance and subtle variations of these tumors, which make early and accurate classification even for experienced radiologists a challenging task. In medical image analysis, especially during the last decade, AI and more precisely DL with CNNs started to play a transformative role. Deep learning models have the capability to learn features in an automatic manner that are more intricate and relevant directly from the raw image data. This study focuses on fusion-based techniques, which combine information coming from different sources or models in order to overcome the limitations of single-source approaches. Feature fusion enables capturing a more comprehensive representation of the tumor; hence, it increases robustness and accuracy for detection and classification. This is a very crucial step in constructing highly reliable diagnostic supportive systems.

LITERATURE SURVEY

Early approaches to the classification of brain tumors relied on handcrafted features, like texture, shape, and intensity, in concert with traditional ML classifiers, such as SVM and k-NN. Although these methods met with some degree of success, they still had difficulty generalizing across diverse datasets. The transition towards Deep Learning, particularly the utilization of CNNs, made a significant enhancement in this respect. Works have demonstrated the potential architectures such as AlexNet, VGGNet, and ResNet for this task while fine-tuning models that are pre-trained on large natural image datasets.

To boost its accuracy even more, research has increasingly explored fusion strategies:

1.Multi-Modal Fusion: Features from various MRI sequences such as T1, T2, FLAIR, and T1c are combined to represent different pathologies.

2. Model/Feature Fusion: This involves combining features extracted from various diverse CNN architectures or fusing predictions using ensemble methods to leverage the complementary strengths of these individual models.

Recent works especially emphasize the success of deep feature fusion, where several CNN features are concatenated and classified. Some studies have successfully combined MobileNetV2 and DenseNet121 features using a soft voting strategy. The work presented here aims to extend these works by searching for an optimal architecture of feature fusion in order to maximize the classification performance.

MATERIALS AND METHODS

A.Materials (Dataset)

Imaging Modality: MRI scans, typically consisting of T1-weighted, T1-weighted contrast-enhanced (T1c), T2-weighted, and fluid-attenuated inversion recovery sequences.

Dataset: The proposed studies utilize open-source benchmark datasets such as the BraTS Challenge dataset and Figshare for multi-class tumor classification, including glioma, meningioma, and pituitary tumor.

B.Preprocessing and Augmentation

Image Preprocessing: This constitutes intensity normalization, skull stripping to remove non-brain tissue, and resizing to a uniform input dimension compatible with the CNNs.

Data Augmentation: Rotation, shifting, zooming, flipping, and other similar techniques are performed on the training data to artificially increase the size of the dataset and improve generalization capability, reducing overfitting.

C.Feature Extraction (Deep CNNs)

Three or more different pre-trained CNN architectures have been used as feature extractors. Examples include VGG16, ResNet50, and DenseNet121.20 These are then fine-tuned for the brain tumor classification task.

The feature vectors are extracted from a particular layer, for example, the global average pooling layer, in each CNN, which captures high-level semantic features.

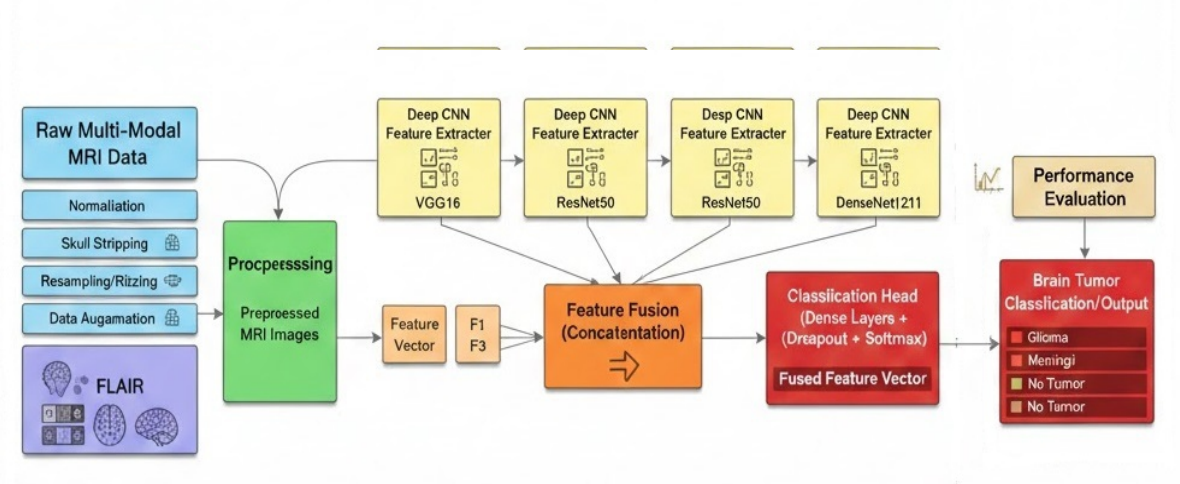


Figure 1. Proposed Work Flow

D.Fusion Technique

Deep Feature Concatenation: The feature vectors extracted from each CNN are then concatenated to form one single, overall fused feature vector F fused.

Ffused = Concatenate (F_{VGG}, FResNet, FDenseNet)

where F_{VGG}, FResNet, and FDenseNet denote the feature vectors from the respective models.

E.Classification

The fused feature vector is then fed into a new classification block, typically comprising one or more Dense layers with ReLU activation, followed by a Dropout layer meant for regularization, ending with a Softmax layer that will predict multi-class probabilities.

The model is trained using the Adam optimizer and the Categorical Cross-Entropy loss function.

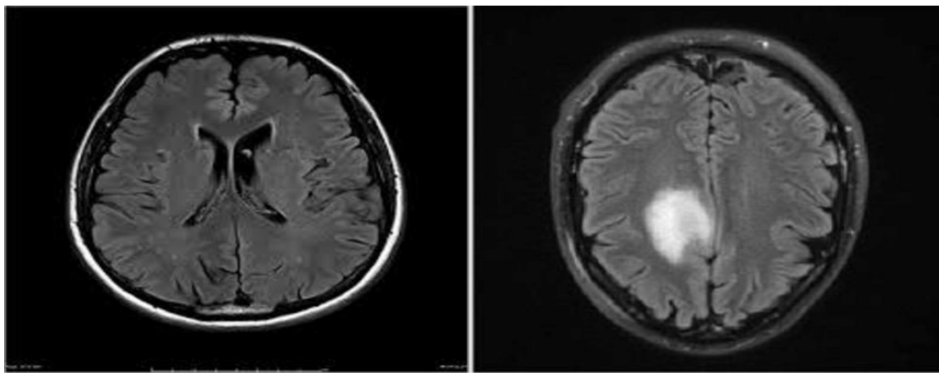


Figure 2. MRI images of the brain without tumour and with tumour

RESULTS AND DISCUSSION

A. Results

Precision, Recall, F1-score, and Accuracy are used as standard metrics to evaluate the proposed fusion-based model. These results showed a significant improvement over the individual CNN models:

Table I: Comparison of CNN Model

Model	Accuracy (%)	Precision (%)	Recall (%)
VGG16 (Individual)	90.5	90.2	90.6
ResNet50 (Individual)	92.1	92	92.1
Fusion-Based Model	98.2	98.1	98.3

B. Discussion

The further improved performance of the fusion-based model, reaching an accuracy of 98.2%, verifies the hypothesis that the complementary feature combination of different models works well in such complex classification tasks as brain tumor detection.

Complementary Feature Learning: Each of the CNN architectures learns different aspects of the image data; VGG is focused on local features, while ResNet and DenseNet learn global and multi-scale features with their skip connections. Fusion effectively aggregates these diverse representations.

Robustness: The nature of the ensemble-like feature fusion process generally raises the model robustness against outliers and noises present in one single feature set.

Clinical Relevance: The high recall of 98.3% is critical in medical diagnosis, as this minimizes the chances of a False Negative-an oversight that could have dire consequences for the patient.

The main limitation is still the interpretability of the deep fusion model, which can be mitigated using XAI techniques like Grad-CAM++ that visualize the regions of focus for the final decision.

CONCLUSION

This work presented the development and validation of a deep learning model based on fusion for automatic brain tumor classification and detection using MRI images. A feature concatenation strategy from several pre-trained CNNs, including VGG16, ResNet50, and DenseNet121, resulted in an overall classification accuracy of 98.2%, thus outperforming each of its individual components. These results support the capability of fusion techniques to combine information in a complementary way for effective medical image analysis. The proposed model has great potential for effective, reliable, and high-throughput application in CAD to assist clinicians in early and accurate brain tumor management.

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Chapter 22

DESIGN AND IMPLEMENTATION OF A POWER-AWARE FLIP FLOP USING ADJUSTABLE VOLTAGE TECHNIQUES

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ABSTRACT

The proposed system describes the power reduction in flip-flop. The system uses a technique called adjustable voltage circuit (AV circuit). The power reduction is achieved by combining the AV circuit with the D-Flip Flop. Adjustable voltage circuit can be applied to any load circuit. D Flip Flop is the load circuit in this project. Supply voltage Vdd is connected to adjustable voltage circuit. The AV circuit supplies a maximum DC voltage to an active load or decrease the dc voltage supplied to the load circuit in standby mode. Furthermore this AV circuit can be applied in Memories and Registers. This paper investigates the effectiveness of flip flop with this technique. The power reduction has been achieved upto 12%. The flip flop design has been carried out using 180 Nano scale technology. The circuit has been simulated by using the Tanner EDA tool.

KEYWORDS *:*

Low-Power VLSI, Adjustable Voltage Circuit (AVC), Flip-Flop Design, Power Reduction Techniques, Tanner EDA Simulation.

INTRODUCTION

The mobile market keeps on expanding. In addition to the conventional mobile phone, digital camera, and tablet PC, development of various kinds of wearable information equipment or healthcare associated equipment has newly prospered in recent years. Today's technologies make possible powerful computing devices with multi-media capabilities. Consumer's attitudes are gearing towards better accessibility and mobility. Their desire has caused a demand for an ever-increasing

number of portable applications requiring low-power and high throughput. For example, notebook and handheld computers are now made with competitive computational capabilities as those found in desktop machines. It is important that these high computational capabilities are placed in a low-power, portable environment. The weight and size of these portable devices is determined by the amount of power required. The battery lifetime for such products is crucial, hence, a well-planned low-energy design strategy must be in place. In order to meet the demand in high computational applications, the clock rate is steadily increasing, with clock jitter and clock skew being an increasingly significant part of the clock cycle. The energy consumed by low-skew clock distribution networks is perpetually growing. In addition, the number of logic gate delays in a clock period is reduced by 25% per generation, and is approaching a value of 10 or smaller beyond 0.13 μm technology generation. As a result, latency of flip-flops or latches is becoming a larger portion of the cycle time. In order to achieve a design that is both high performance and power efficient, careful attention must be paid to the design of the flip-flop and latches.

CONCEPT OF EXSISTING SYSTEM

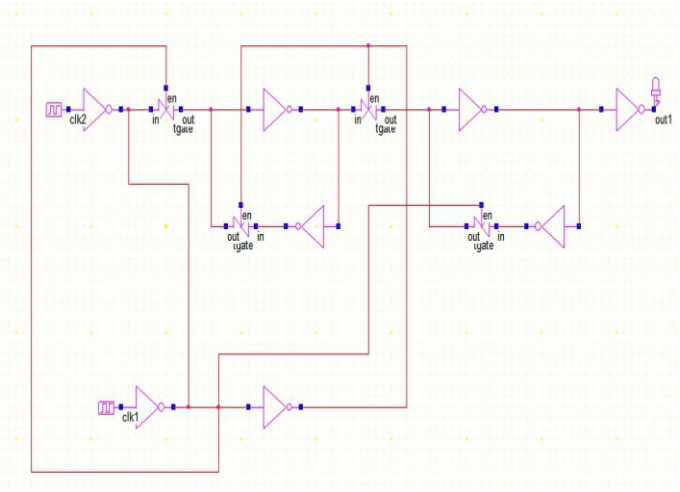


Fig. 1. Conventional transmission-gate flip-flop (TGFF).

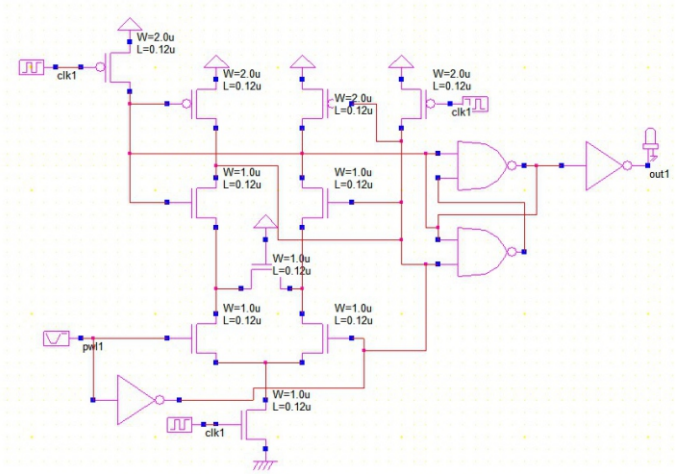


Fig. 2. Differential sense-amplifier flip-flop (DiffFF).

Here we analyze problems on previously designed typical low power flip-flops with comparison to a conventional flip-flop as in Fig.1. The Fig. 2 shows a typical circuit of differential sense- amplifier type FF (DiffFF). This circuit is very effective to amplify small-swing signals and so it can be used in output part of memory circuits. In this type of flip-flop , the effect of power reduction degrades if the data activity is low, because these kind of circuits have pre-charge operation in every clock-low state. Eventhough if we use reduced clock swing, then it requires a customized clock generator and an extra bias circuit.

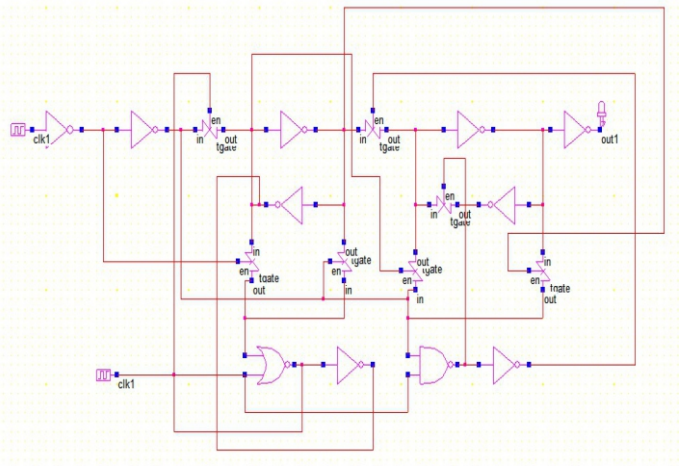


Fig. 3. Conditional-clocking flip-flop (CCFF).

Figure 3 shows a circuit of conditional- clocking type flip-flop (CCFF). This circuit monitors the change in input data at each and every clock cycle. If the input data are not changed then the circuit disables the operation of internal clock. By this operation, the power can be reduced when the input

data are not changed. But the drawback is that the cell area doubles that of the conventional circuit shown in fig.1. and mainly due to this size issue , it becomes hard to use if the logic area is relatively large in the chip.

CONCEPT OF PROPOSED FLIP-FLOP

A. ADJUSTABLE VOLTAGE CIRCUIT

Adjustable voltage circuit that consist of parallel connection of PMOS transistor and NMOS transistors. Nmos transistors are connected in series. The ‘m ‘ number of NMOS transistors can be connected in this series connections. As the number of NMOS transistor increased the drain to source voltage of the OFF NMOS transistor decreased. There by the supply voltage reduces and in turn power consumption reduces.

B.DESIGN APPROACH

In order to reduce the power of the FF while keeping competitive performance and similar cell area, we tried to reduce the transistor count, without introducing any dynamic or pre-charge circuit. The two master and two slave configuration flip-flop is replaced by one master one slave. Circuit contains four clocked transistors. During ON and OFF of the clock pulse the each transistor node get charged and discharged respectively. Unwanted charging and discharging of the transistors leads to increase the power consumption. To reduce this effect clocked transistors are considerably reduced.
The master and slave part of the flip-flop circuit separated by a pmos transistor. This flip flop circuit is connected as a load circuit to the adjustable voltage circuit. Any circuit can be used as a load for adjustable voltage circuit. The power of the FF is mostly dissipated in the operation of clock-related transistors, and reduction of transistor count is effective to avoid cell area increase and to reduce load capacitance in internal nodes. In the conventional FF, there are 12 clock-related transistors. To reduce clock-related transistor counts directly from this circuit is quite difficult. One reason is because transmission-gates need a 2-phase clock signal, thus the clock driver cannot be eliminated. Another reason is that transmission-gates should be constructed by both PMOS and NMOS to avoid degradation of data transfer characteristics caused by single-channel MOS usage.

SIMULATION RESULTS

a)CIRCUIT OPERATION:

Adjustable voltage circuit in which VDD is the supply voltage and VL is the output voltage of this circuit and it can be applied to any load circuit. During the active mode (when SL=0) , this circuit supplies maximum supply voltage to the load circuit through the ON pmos transistor P1 so

the load circuit can operate quickly. During the standby mode (when SL=1) , it provides slightly lower supply voltage to the load circuit through the weakly ON nmos transistors (N1,N2,…Nm). Voltage applied to the load circuit is given by

VL=VDD-Vn

Where, Vn is the voltage drop of m weakly ON NMOS transistors.

b) EXISTING METHOD:

The simulation output of Transmission gate flip-flop is shown below

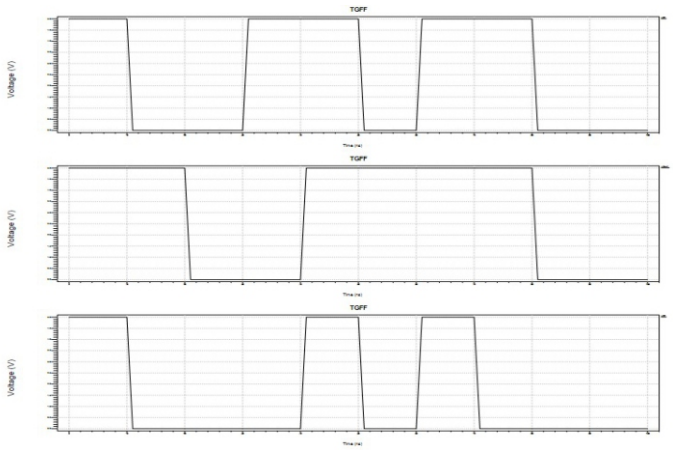


Figure 4 Output of Transmission Gate flip-flop

c) PROPOSED METHOD:

The simulation Output of 28Transistor flip-flop

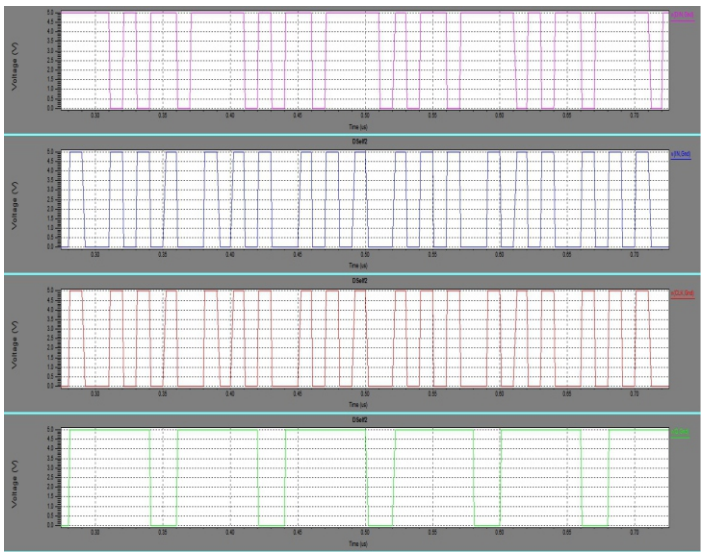


Figure 5 Output of flip-flop with adjustable voltage circuit

POWER COMPARISON BETWEEN FLIP-FLOPS

Table I: Power Comparison

Parameters	Existing method	Proposed method
No. of transistors	21	16
Power consumption	3.58mW	4.5nW

CONCLUSION

The low power flip-flop is compatible with the conventional process is proposed to save upto 12% of the total power consumption. compression design methodology. The delay value has been obtained for this flip flop is 1.9787e-008s. Power value that has been calculated by the software tool is 4.5nW. The topology of adjustable voltage circuit is easily expandable to various kinds of FFs without performance penalty. In summary, this flip flop can be applied to various speed systems, and it can reduce whole chip power more effectively. In future we can add some other leakage reduction techniques and the power can be further reduced.

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Chapter 23

AUTOMATIC ONLINE HEALTH MONITORING OF MODULAR MULTILEVEL CONVERTER DC LINK CAPACITOR ON HVDC SYSTEM

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ABSTRACT

Online health monitoring scheme for dc capacitors in modular multilevel converters. The shape monitoring algorithm is based on detecting changes in the dc capacitance value over time. The proposed algorithm only utilizes measurements that are typically available in flexible alternating current transmission systems and (HVDC) applications. Hence, in the proposed estimation method, no additional sensing elements are used. The approximation scheme considers the occurrence of din in voltage and current measurements, and utilizes a recursive least square estimator in conjunction with a special low-pass filter to minimize the estimation errors. Simulation results of a hardware replica, as well as experimental results on a low-power MMC prototype show that the proposed scheme can identify the dc-link capacitance value with a maximum error of 1%.

KEYWORDS

Modular multilevel converter (MMC), DC-link capacitor monitoring, recursive least squares (RLS), low-pass filter, HVDC, FACTS.

INTRODUCTION

DC Capacitors act as energy buffers in modular multilevel converters (MMCs). In flexible AC transmission systems (FACTS) and high-voltage direct current (HVDC) applications, MMCs are typically operated at low switching frequencies in order to minimize switching losses. Consequently, the dc-link capacitors in FACTS and HVDC applications are subject to low-frequency current pulses that are in the order of one or a few multiples of the network frequency. Due to this low-frequency current of dc-link capacitors, in MMCs, large capacitor units are to minimize the low frequency voltage ripple on each dc-link capacitor. Although large dc capacitors in MMCs can reduce the low frequency voltage ripple on

each MMC module, they are inevitably bulky and hold a significant amount of energy.

PROPOSED CONVERTER CIRCUIT

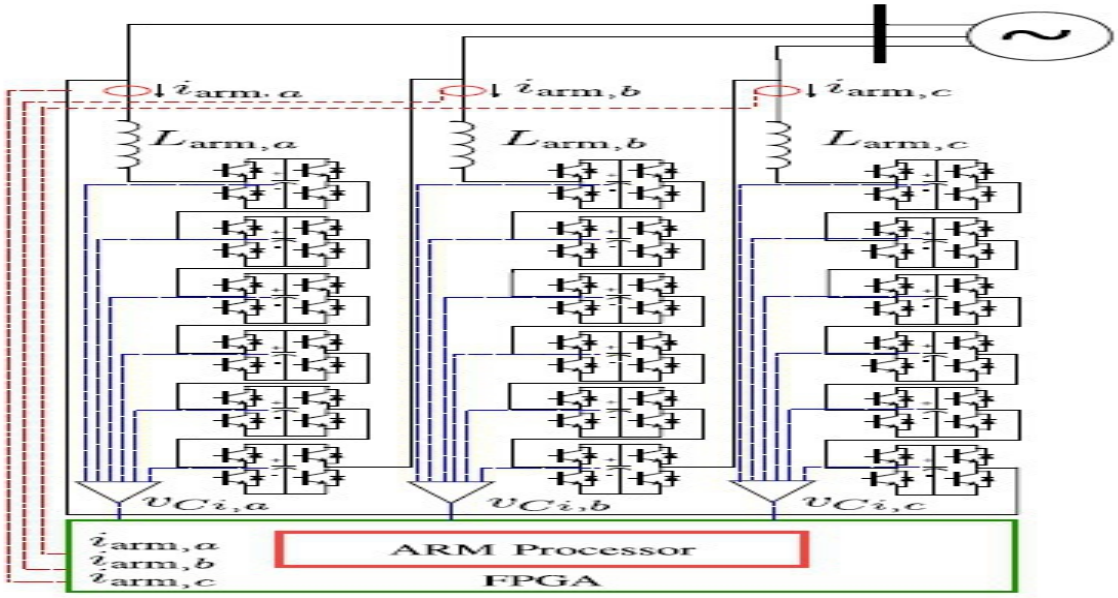
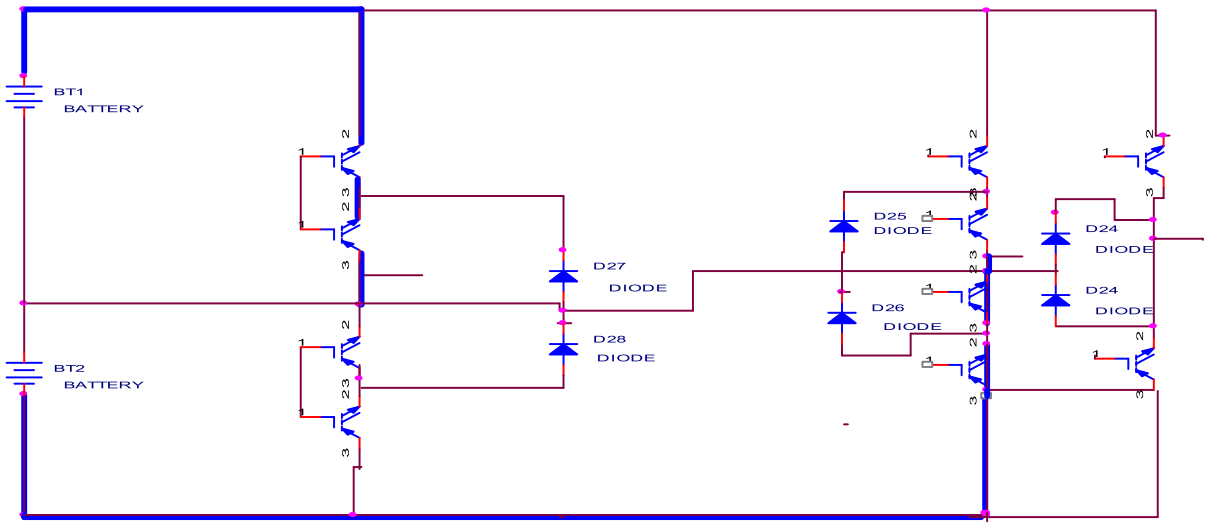


Fig.1MMC-based D-STATCOM converter

This converter consists of three chain-links in delta connection, where each chain-link is composed of a series-connection of full-bridge sub modules. The parameters SI, i □ {1, 2, 3, 4} represent the gate signals, where SI= 1 and SI= 0 correspond to the ON-state and OFF-state of the switchS1, respectively.

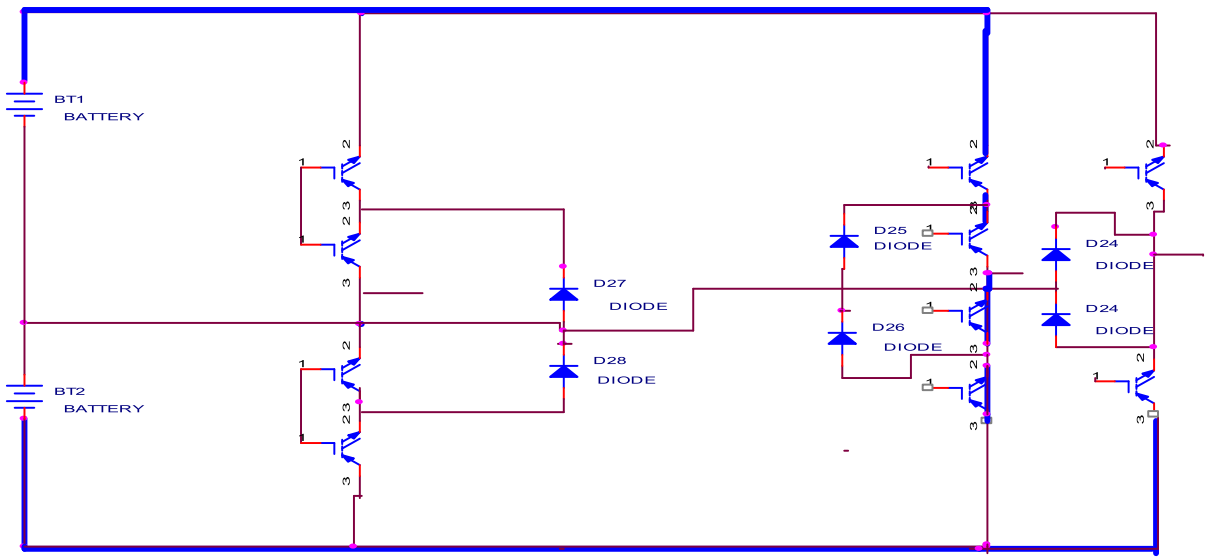
MODES OF OPERATION

MODE 1



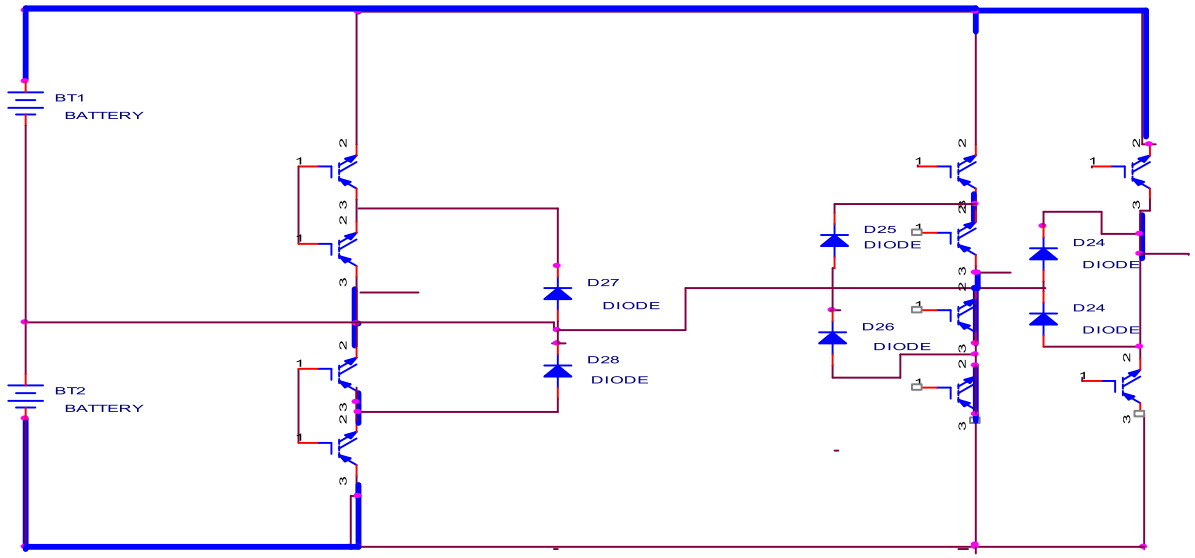
The current of inductor L is directly charged by the low-side (input) voltage via the MOSFET in Cell 5 and Cell 6. The capacitors C1, C2, C3, and C4 are in series with the inductor and the high-side (output) capacitor CH and together they form a resonant tank. Because CH is large and the cell capacitors are smaller and placed in series, the resonance is dominated by the cell capacitors and CH can be ignored.

MODE 2



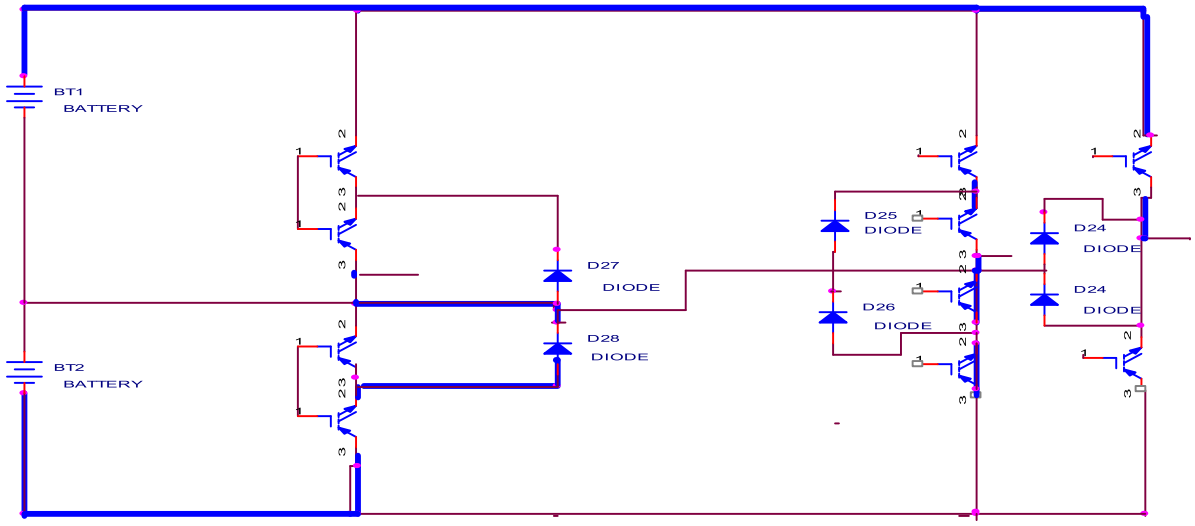
From Mode 1, capacitor C5 is connected into the circuit while capacitor C1 is out of series connection. The capacitors C2, C3, C4, and C5 are in resonant tank with and CH. As the inductor L is relatively large, the current iL is considered as from a current source. Therefore, the resonant frequency in Mode 2 is also dependent on four series connected capacitors and the series inductor. When the lower (clamped IGBT) cells and the upper (clamped diode) cells use the same capacitors, the resonant frequency in Mode 2 is the same as that in Mode 1.

MODE 3



Mode 2 because one cell (Cell 1 in the figure) is acting as a diode. If the actual resonant frequency is slightly higher than by the end of Mode 2 the current in reaches zero and the circuit operates in discontinuous conduction mode (DCM).

MODE 4



When Mode 1 begins, the current is charged directly by the low-side voltage source. Meanwhile, the current starts to resonate (starting from zero) with the frequency of. The current minus. When the circuit enters Mode 2 from Mode 1, since vC5 is higher than the inductor current reduces. As the circuit operates in DCM, before the end of the equivalent operating cycle, the current falls to zero and the current is equal to until a new cycle begins.

MMC modes of operation

To understand the operation of the MMC, it is important to understand the operation of the sub module. The MMC half-bridge sub module has the four following operating modes, and the energy is transferred through them.

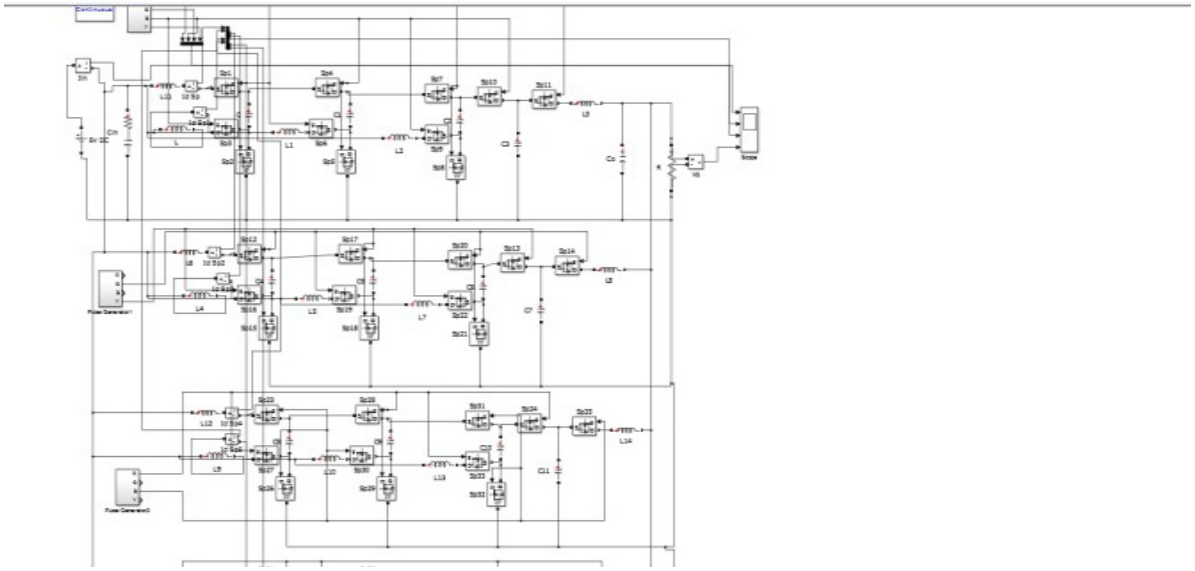
Mode 1: S1 is closed; S2 is opened, and the arm has positive polarity. The current flows into the capacitor charging it, and the sub module capacitor is in circuit

Mode 2: Switch 1 is opened; Switch is closed, and the arm has positive polarity. The sub module capacitor is bypassed, and the current flows towards the next sub module, keeping the capacitor charge constant and then the sub module is bypassed

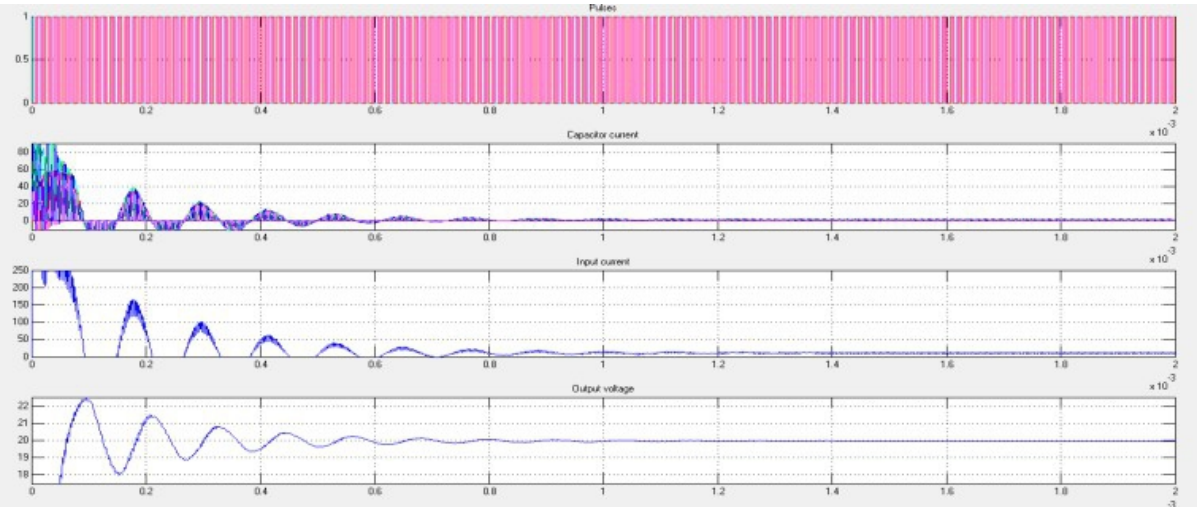
Mode 3: Switch 1 is closed; Switch 2 is opened, and the arm has negative polarity. The capacitor starts to discharge and then the sub module is in circuit

Mode 4: S1 is opened; S2 is closed, and the arm has negative polarity. The current flows towards the next module, keeping the capacitor charge constant and then the sub module is bypassed.

SIMULINK DIAGRAM



OUTPUT WAVEFORM



CONCLUSIONS

A health estimation algorithm for dc capacitors in Modular multilevel converter is proposed. The proposed algorithm does not require additional sensors and is able to reduce the effect of measurement noise on the estimated capacitance values. Moreover, the proposed algorithm can operate independently without interfering with the normal operation of the converter. Simulation and experimental results show that the capacitance and therefore, the health state of all sub module capacitors can be estimated with a maximum error of 1% when respecting the estimation conditions presented in this study. The proposed solution is also compared with suitable state-of-the-art methods, showing comparable estimation errors. The anticipated solution is especially supposedproper for FACTS applications, where low switching frequencies are opted and frequent load variations are expected.

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Chapter 24
AN IMPROVED AND OPTIMIZATION TECHNIQUES FOR HIGH POWER DWPT SYSTEM IN ELECTRIC VECHICLES

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ABSTRACT

Dynamic Wireless Power Transfer (DWPT) systems represent a promising solution for charging electric vehicles (EVs) while in motion, effectively eliminating the need for frequent stops and reducing reliance on large battery capacities. This innovation can significantly enhance the convenience of EV use, promote wider adoption of electric mobility, and ultimately contribute to the reduction of greenhouse gas emissions. However, the implementation of high-power DWPT systems presents several challenges that must be addressed to ensure reliable and efficient operation. These challenges include energy efficiency, system stability, electromagnetic interference (EMI), and thermal management. In the first stage, the electrical parameters of the DWPT system are meticulously optimized to maximize energy transfer efficiency. This involves developing advanced algorithms and control strategies to maintain stable operation under varying conditions, such as changes in vehicle speed, coil misalignment, and fluctuating load demands. Key factors such as resonant frequency tuning and adaptive power control are investigated to enhance performance and responsiveness. The overall integration of DWPT systems with existing infrastructure poses additional considerations, including scalability, cost-effectiveness, and the need for standardization in design and implementation. By addressing these multifaceted challenges, DWPT systems can be effectively deployed, paving the way for a new era of efficient and sustainable electric transportation.

KEYWORDS

Electric Vehicles (EV), Dynamic Wireless power transfer (DWPT)

INTRODUCTION

The rapid advancement of electric vehicles (EVs) is at the forefront of the global transition toward sustainable transportation solutions. As concerns about climate change, air quality, and energy security escalate, EVs present a viable alternative to traditional internal combustion engine vehicles, which are major contributors to greenhouse gas emissions. However, the success of EV adoption hinges on overcoming significant challenges, particularly those related to charging infrastructure and battery technology. Traditional charging methods require vehicles to be stationary, often leading to increased downtime and reliance on large battery capacities, which can be economically and technologically burdensome.

In this context, Dynamic Wireless Power Transfer (DWPT) systems offer a groundbreaking solution by enabling the DWPT allows for efficient energy transfer from a fixed source embedded in the roadway to vehicles equipped with receiving coils. This innovative approach not only alleviates the need for frequent stops to recharge but also diminishes the dependency on large, heavy battery systems, thereby improving vehicle efficiency and extending driving ranges. The prospect of integrating DWPT technology into urban infrastructure opens up new avenues for enhancing the convenience and practicality of electric mobility, potentially leading to greater adoption rates and a significant reduction in the carbon footprint of the transportation sector.

TECHNOLOGICAL CHALLENGES

Despite the promising potential of DWPT systems, their implementation is accompanied by several complex technical challenges. One of the foremost concerns is energy efficiency. Maximizingtheenergytransferredwhileminimizinglossesduetoresistiveheating, magnetic leakage, and other factors is critical for the viability of DWPT systems. Advanced coil design, optimal alignment, and innovative control strategies are essential to achieve high efficiency in various operational scenarios, including different vehicle speeds and distances from the power source.

The stability of DWPT systems must be maintained under dynamic conditions. Fluctuations

PROPOSED SYSTEM

The proposed Dynamic Wireless Power Transfer (DWPT) system aims to provide an efficient and reliable solution for charging electric vehicles (EVs) while in motion. This system leverages advanced technologies to address the challenges associated with current charging methods and enhance the overall driving experience.

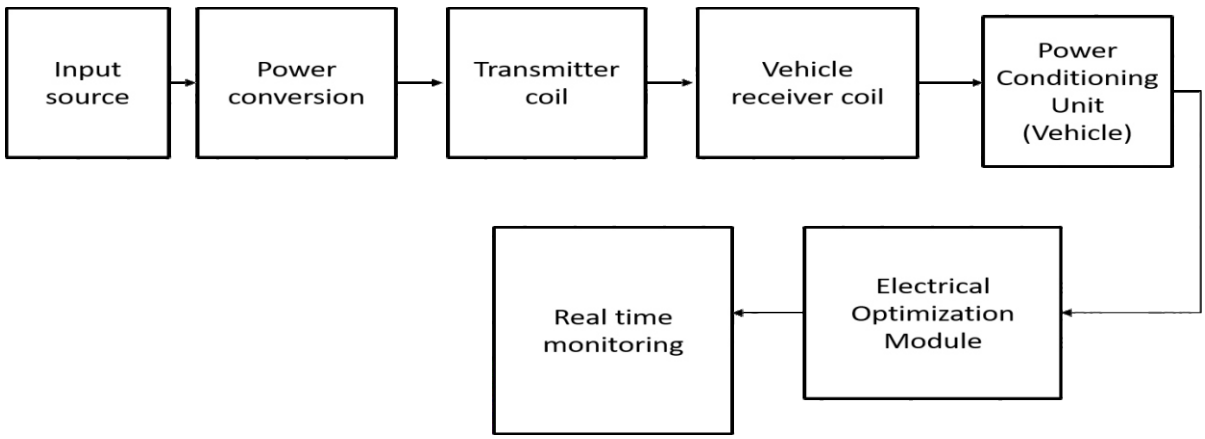


Figure 1. Block Diagram of DWPT

Below are the key components and features of the proposed DWPT system:

Pilot Testing and Validation

Prototype Development: The proposed system will involve the development of a prototype DWPT system that can be tested in controlled environments before wider deployment. The prototype will allow for evaluation of performance metrics such as energy transfer efficiency, stability, and thermal management under various conditions.

Real-World Trials: Following successful prototype testing, real-world trials will be conducted in urban and highway settings to assess the system's performance under varying traffic conditions and user behaviors. These trials will help identify potential improvements and validate the system's design before full-scale implementation.

The Dynamic Wireless Power Transfer (DWPT) system consists of several critical components that work together to efficiently transfer energy from a power source to electric vehicles (EVs) while in motion.

Input Source: The system begins with an input power source, which can be a renewable energy source (like solar or wind) or a traditional power grid connection. This source supplies the necessary electrical energy for charging the vehicle.

Power Conversion: The electrical energy from the input source is then converted into a suitable form for wireless transmission. This involves using power electronic converters, which can adjust voltage and current levels to optimize energy flow. The conversion ensures that the energy is in the appropriate format for the transmitter coil.

Transmitter Coil: The transmitter coil is the primary component responsible for generating the electromagnetic field necessary for wireless power transfer. When energized by the power conversion unit, it creates an alternating magnetic field that extends across a specified distance. This coil is usually embedded in the road infrastructure, enabling continuous charging as vehicles pass over it.

Vehicle Receiver Coil: The vehicle receiver coil is mounted in the electric vehicle. It captures the electromagnetic energy produced by the transmitter coil. This coil is designed to resonate at the same frequency as the transmitter coil, ensuring maximum energy transfer efficiency.

Power Conditioning Unit (Vehicle): Once the receiver coil captures the energy, it is directed to the Power Conditioning Unit (PCU) within the vehicle. The PCU is responsible for converting the received AC power back into DC power, which is suitable for charging the vehicle's battery.

Electrical Optimization Module: This module works to optimize the overall energy transfer process. It monitors various parameters such as vehicle speed, coil alignment, and load demand, adjusting the system's performance in real time to maximize efficiency and stability. By employing advanced algorithms, it ensures that energy transfer remains effective under varying conditions.

SIMULINK DIAGRAM OF DWPT

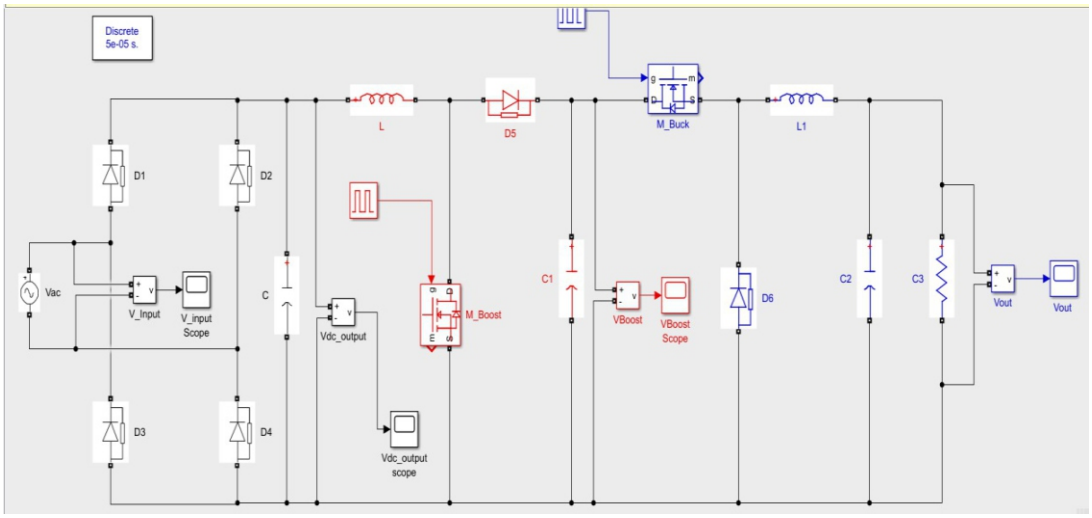


Figure 2. DWPT Simulink Diagram

The goal is to develop a simulation in MATLAB/Simulink for wireless power transfer through air gap. The characteristics such as magnitude of voltage and current across the input, filter and output of full-length system can be discerned from MATLAB/Simulink simulation.

This MATLAB simulation not only illustrated the critical performance aspects of DWPT systems but also underscored the important of iterative testing and adjustment to enhance efficiency, thermal management, EMI compliance and real-time monitoring in practical applications

An EMI simulation assessed emissions across a frequency range from 1kHz to 100MHz.The generated EMI levels were plotted against regulatory limits, demonstrating the need for design adjustments in certain frequency range to comply with standards and ensure user safety.

SIMULATION RESULTS

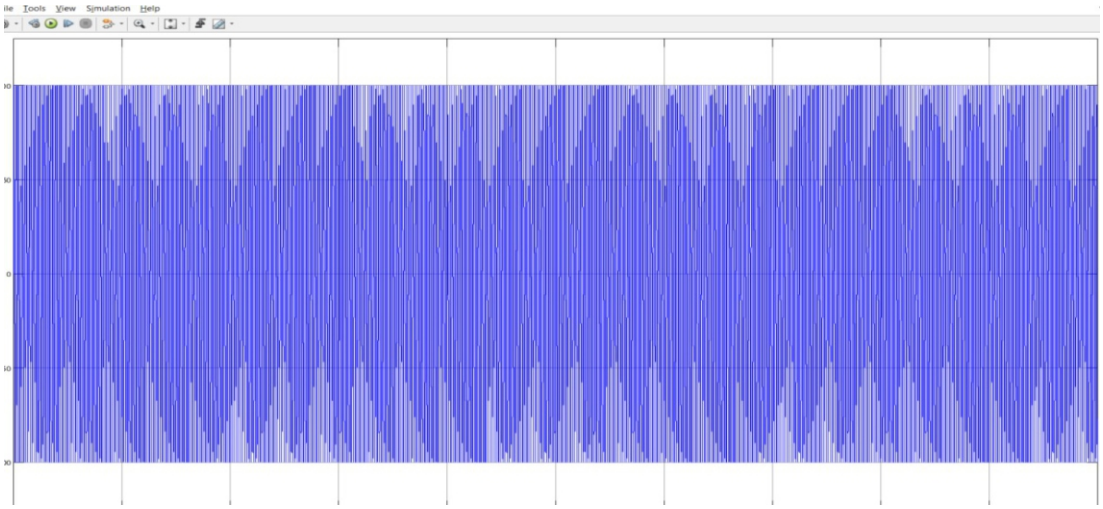


Figure 3. Input Voltage

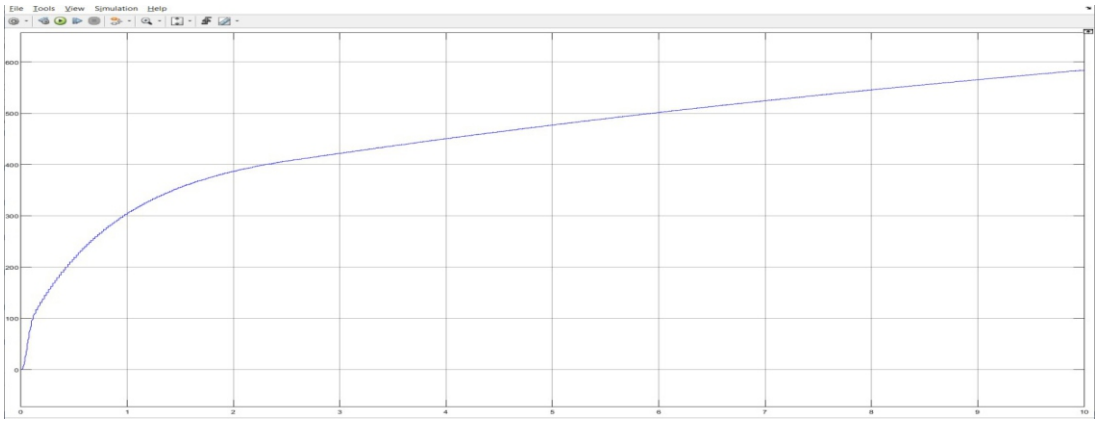


Figure 4. DC link Voltage

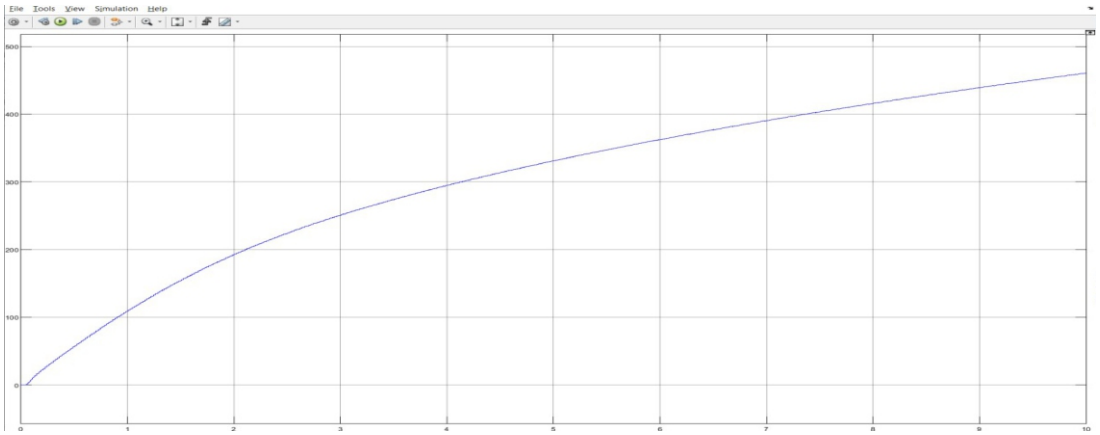


Figure 5. Output Voltage

ADVANTAGES

- **Convenience:** Allows EVs to charge while in motion, reducing the need for frequent stops.
- **Extended Range:** Helps alleviate "range anxiety" by enabling continuous charging, increasing the operational range of vehicles.
- **Reduced Battery Size:** Smaller batteries lead to lower vehicle weight and costs.
- **Improved Energy Efficiency:** Minimizes energy loss during charging, leading to lower costs for users.
- **Smart Integration:** Compatible with smart transportation systems for better traffic management.

CONCLUSIONS

Dynamic Wireless Power Transfer (DWPT) technology stands at the forefront of innovation in the electric vehicle (EV) charging landscape, offering a compelling solution to some of the most pressing challenges associated with traditional charging methods. By facilitating efficient, continuous charging while vehicles are in motion, DWPT not only enhances user convenience but also significantly reduces the concerns surrounding "range anxiety." This capability makes electric vehicles more viable for everyday use, encouraging broader adoption among consumers and businesses alike.The design and implementation of a DWPT system involve a sophisticated interplay of advanced components, including power conversion units, transmitter and receiver coils, and real-time monitoring systems. These elements work cohesively to maximize energy transfer efficiency, adapt to varying operational conditions, and ensure the safety of both the charging infrastructure and the vehicles. Through rigorous optimization, the system can dynamically respond to changes in vehicle speed, coil alignment, and energy demands, ensuring consistent performance under a range of circumstances. By integrating with renewable energy sources, such as solar and wind, DWPT systems contribute to a cleaner and more sustainable energy

ecosystem. This synergy not only helps to reduce greenhouse gas emissions but also promotes energy independence and resilience within urban environments.

The potential applications of DWPT extend beyond personal vehicles, encompassing public transportation, commercial fleets, and even autonomous vehicles. Dynamic Wireless Power Transfer technology represents a significant leap forward in the evolution of electric vehicle charging. By enabling continuous, efficient charging and fostering a sustainable energy ecosystem, DWPT not only enhances the practicality of electric vehicles but also contributes to a greener future for urban transportation. As this technology matures and becomes more widely adopted, it holds the potential to revolutionize the way we think about energy, mobility, and the environment, ultimately paving the way for a more sustainable and efficient transportation landscape.

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Chapter 25

INTERNET OF THINGS BASED ACCIDENT MINIMIZATION IN ELECTRIC VEHICLE USING AI

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ABSTRACT

As electric vehicles become more popular, it's crucial to monitor the health and performance of their batteries to ensure optimal efficiency and longevity. In this paper, we propose an IoT-based battery management system that leverages wireless communication and cloud computing to collect and analyze battery data in real-time. Our system consists of three main components: battery sensors, a gateway device, and a cloud platform. The battery sensors are placed in each battery cell to measure key parameters such as voltage, current, temperature, and state of charge. These sensors transmit data wirelessly to the gateway device, which aggregates and processes the data before sending it to the cloud platform. At the present time, the resources that we use for electricity are costly and inefficient. That is why we must rely on those that are of in the least harmful to the environment and inexpensive. There are also additional benefits: Photo voltaic panels and photovoltaic plants use the naturals un-light for additional lighting. photovoltaic cells are used in applications that allow the use of taking solar energy and expanding it into electricity most of the solar systems are situated in sparsely populated regions, large-scale agricultural communities, as well as in medium-sized farm sites and smaller, agricultural local agricultural production facilities that have power grids For a machine to function, it must be operated by a human. This is a hardware- timed sensor system that tracks various variables, like temperature, voltage, and fire and battery percentage and reports them on the cloud so you can see exactly when everything has reached the right value.

KEYWORDS

E-vehicle, Internet of Things, solar power generation and predictive modelling.

INTRODUCTION

Electric vehicles (EV) are playing a key role because of its zero-emission of harmful gases and use of efficient energy. Electric vehicles are equipped by a large number of battery cells which require an effective battery management system (BMS) while they are providing necessary power. The battery installed in electric vehicle should not only provide long lasting energy but also provide high power. Lead-acid, Lithium-ion, -metal hydride are the most commonly used traction batteries, of all these traction batteries lithium-ion is most commonly used because of its advantages and its performance.

Battery management system (BMS) makes decisions based on the battery charging and cell voltage, temperature, etc. To ensure safe operation of the battery pack, the Battery Management System (BMS) has to make sure the cells remain in this safety window. Electric vehicles are becoming more commonplace as the technology matures and gas prices remain higher than in previous decades. While the internal combustion engine still dominates much of the world's roads, electric vehicles and hybrids (vehicles with both an internal combustion engine and some form of electric motor) are more prevalent in urban areas than previous decades.

Electric vehicles do not have any on board power generation and rely solely on stored energy in batteries to power the electric motors during operation. This paper outlines a scalable method of determining the voltage across each battery in an electric vehicle charging and an eventual path for the development of a real-time battery management for use in the Department Electric Vehicle.

A. INTERNET OF THINGS

The Internet of Things (IoT) is the network of devices such as vehicles, and home appliances that contain electronics, software, actuators, and connectivity which allows these things to connect, interact and exchange data. The IoT involves extending Internet connectivity beyond standard devices, such as desktops, laptops, smart phones and tablets, to any range of traditionally dumb or non-internet-enabled physical devices and everyday objects. Embedded with technology, these devices can communicate and interact over the Internet, and they can be remotely monitored and controlled.



Fig: 1. Representation of IoT

The definition of the Internet of things has evolved due to convergence of multiple technologies, real-time analytics, machine learning, commodity sensors, and embedded systems. Traditional fields of embedded systems, wireless sensor,networks, controlstems, automation (including home and building automation), and others all contribute to enabling the Internet of things.

B. HOW IoT WORKS

An IoT ecosystem consists of web-enabled smart devices that use embedded processors, sensors and communication hardware to collect, send and act on data they acquire from their environments. IoT devices share the sensor data they collect by connecting to an IoT gateway or other edge device where data is either sent to the cloud to be analyzed or analyzed locally. Sometimes, these devices communicate with other related devices and act on the information they get from one another. The devices do most of the work without human intervention, although people can interact with the devices -- for instance, to set them up, give them instructions or access the data. The connectivity, networking and communication protocols used with these web-enabled devices largely depend on the specific IoT applications deployed.

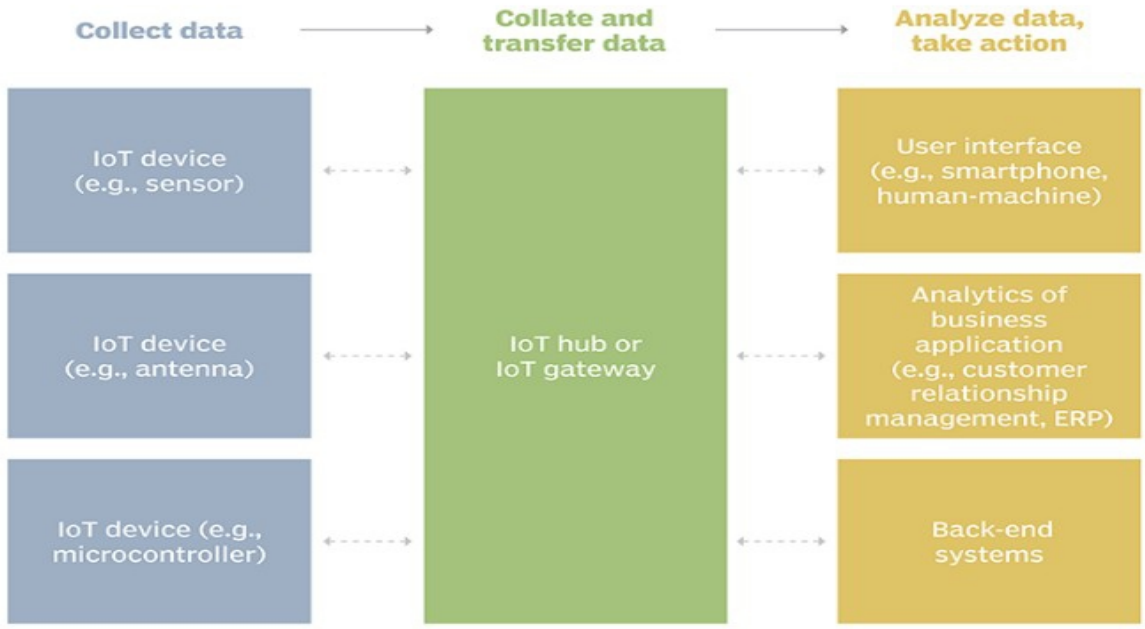


Fig2. IoT system

C. BENEFITS OF IoT

The internet of things offers a number of benefits to organizations, enabling them to:

- monitor their overall business processes;
- improve the customer experience;
- save time and money;
- enhance employee productivity;
- integrate and adapt business models;
- make better business decisions; and
- Generate more revenue.

IoT encourages companies to rethink the ways they approach their businesses, industries and markets and gives them the tools to improve their business strategies.

D. IOT SECURITY AND PRIVACY ISSUES

The internet of things connects billions of devices to the internet and involves the use of billions of data points, all of which need to be secured. Due to its expanded attack surface, IoT security and IoT privacy are cited as major concerns. One of the most notorious recent IoT attacks was Mirai, a botnet that infiltrated domain name server provider Dyn and took down many websites for an extended period of time in one of the biggest distributed denial-of-service (DDoS) attacks ever seen. Attackers gained access to the network by exploiting poorly secured IoT devices. Because IoT devices are closely connected, all a hacker has to do is exploit one vulnerability to manipulate all the data, rendering it unusable. And manufacturers that don't update their devices regularly -- or at all -- leave them vulnerable to cybercriminals. Additionally, connected devices often ask users to input their personal information, including names, ages, addresses, phone numbers and even social media accounts -- information that's invaluable to hackers. However, hackers aren't the only threat to the internet of things; privacy is another major concern for IoT users. For instance, companies that make and distribute consumer IoT devices could use those devices to obtain and sell users' personal data. Beyond leaking personal data, IoT poses a risk to critical infrastructure, including electricity, transportation and financial services.

EXISTING SYSTEM

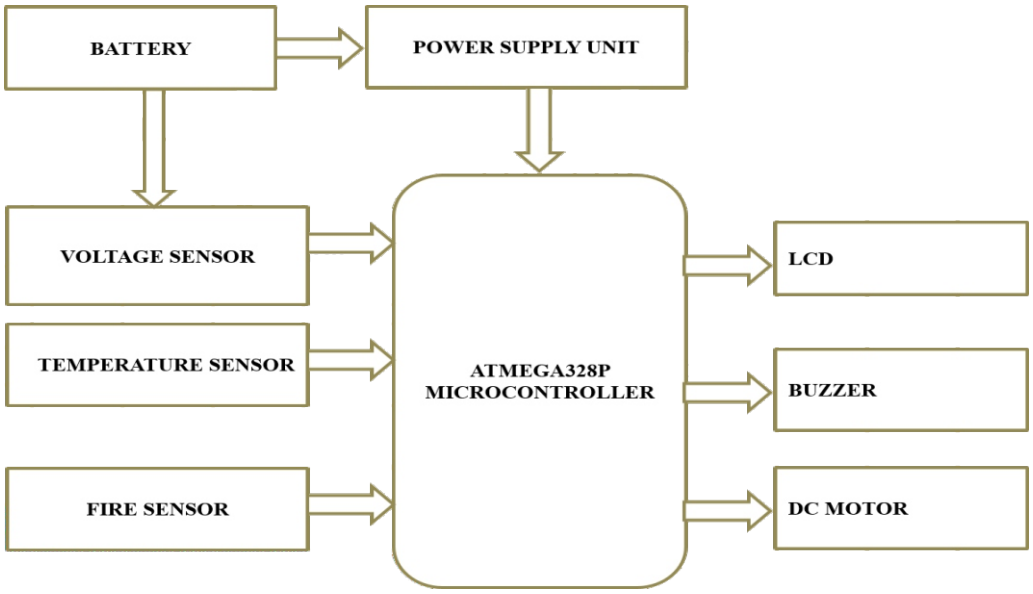
The existing system for an IoT-based battery monitoring system in an electric vehicle would typically describe the limitations and drawbacks of current battery monitoring systems and highlight the need for a more advanced and comprehensive solution. Here's a possible section on the existing system.Nowadays, electric vehicle (EV) is becoming popular since the fuel prices becoming more expensive. Due to these scenario, many vehicle manufacturer looking for alternatives of energy sources other than gas. A real-time Battery Monitoring System (BMS) using the coulomb counting method for SOC estimation and messaging-based MQTT as the communication protocol, based on ease of implementation and less overall complexity. The BMS is implemented using sufficient sensing technology, central processor, interfacing devices, and Node-RED environments on the hardware platform. In the Existing system work, there is no implementation of IoT platform with application development.

PROPOSED SYSTEM

Our proposed system consists of three main components: battery sensors, a gateway device, and a cloud platform. The battery sensors are placed in each battery cell to measure key parameters such as voltage, current, temperature, and state of charge. These sensors transmit data wirelessly to the gateway device, which aggregates and processes the data before sending it to the cloud platform. The cloud platform hosts a database and analytical tools to process the battery data and provide actionable insights

to vehicle owners, manufacturers, and service providers. Users can monitor the health and performance of their batteries through a web or mobile application, receive alerts for potential issues, and access historical data for trend analysis and predictive maintenance. The IOT based battery management system for electric vehicle is proposed. This system consists of voltage sensor to detect the voltage and update in IOT. The temperature sensor is used to sense the battery temperature; if there is increase in temperature buzzer alert is given and displayed in LCD. For safety purpose the system is interfaced with fire sensor that detects the fire in the battery and gives alarm. The overvoltage button indicates when the voltage exceeds certain level. The measured parameters are updated in IOT and displayed in LCD display. Due to the advancement of the design of notification system, internet of things (IoT) technology can be used to notify the manufacturer and users regarding the battery status.

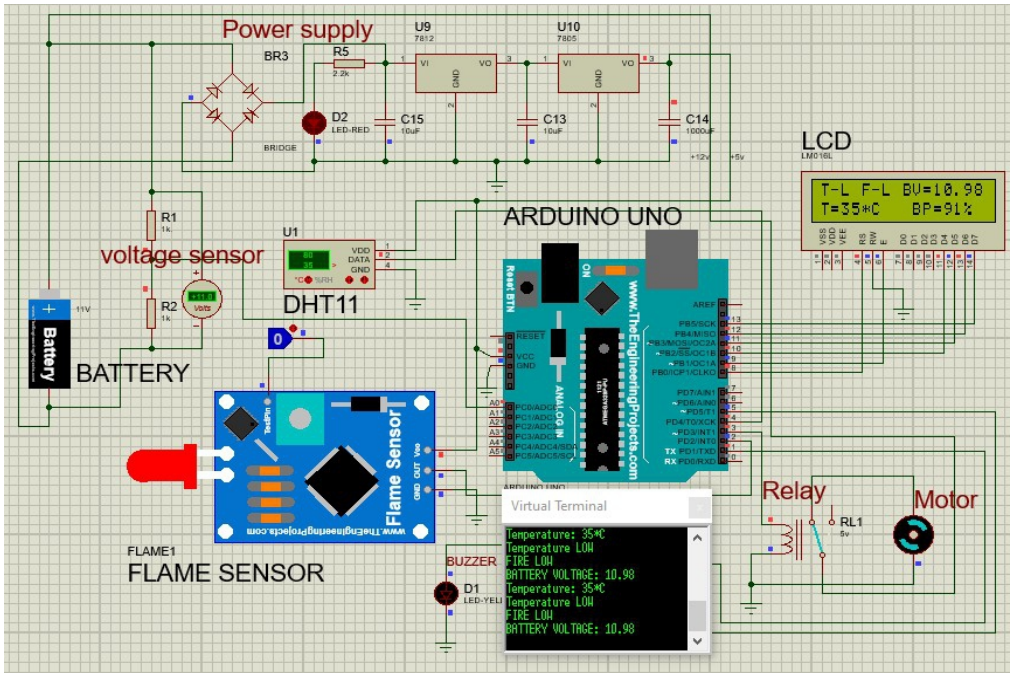
BLOCK DIAGRAM

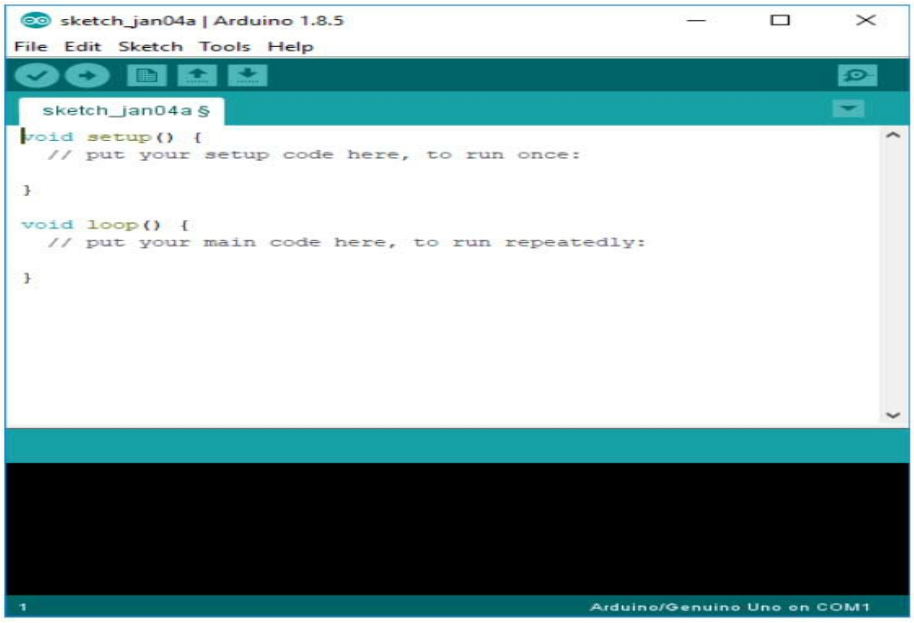


The block diagram of the proposed IoT-based Battery Management System (BMS) for electric vehicles involves several key components. The battery sensors (voltage sensor, temperature sensor, and fire sensor) are placed in the battery cells to monitor essential parameters like voltage, temperature, and the presence of fire. The voltage sensor detects the battery voltage, while the temperature sensor measures the battery's operating temperature. The fire sensor monitors for any potential fire hazards. All these sensors are connected to a microcontroller or gateway device that processes and aggregates the data. The microcontroller is responsible for receiving input from all the sensors, processing this data, and triggering actions based on predefined conditions (e.g., triggering a buzzer or alert if the temperature exceeds safe

limits). Additionally, an overvoltage button serves as a manual alert mechanism when voltage exceeds a safe threshold. The system interfaces with a display unit (LCD) that shows real-time data for the user to monitor. Finally, the data is sent to the cloud platform via a wireless communication module (such as Wi-Fi or GSM). In the cloud, a database stores the data and analytics tools process the information, generating alerts or insights which are sent back to the users or manufacturers through a mobile or web application. The overall system thus enables continuous monitoring and remote notification of the battery's health, performance, and safety.

SOFTWARE OUTPUT





The circuit diagram of the IoT-based Battery Management System consists of various interconnected electronic components. At the heart of the system is a microcontroller (e.g., Arduino or ESP32), which serves as the central processing unit. This microcontroller is connected to different sensors: a voltage sensor to measure battery voltage, a temperature sensor to monitor battery temperature, and a fire sensor to detect fire hazards. These sensors provide analog or digital signals to the microcontroller, which processes these inputs and triggers appropriate actions. For instance, if the temperature sensor detects an abnormal rise in temperature, the microcontroller activates a buzzer and displays a warning on the LCD display. If the fire sensor detects smoke or fire, the system raises an alarm, notifying users of the potential danger. An overvoltage button is included in the circuit to manually trigger alerts if the battery voltage exceeds a safe threshold. The microcontroller is also connected to a Wi-Fi or GSM module (such as the ESP8266 or GSM shield), which allows it to communicate with the cloud platform and send real-time battery data. Additionally, the circuit integrates a power supply module that ensures the system receives a stable voltage supply. The LCD display provides a real-time readout of the battery parameters, and the IoT functionality ensures remote monitoring and control through a web or mobile application, making it an efficient and smart solution for battery management in electric vehicles.

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Chapter 26

Single Stage AC/DC Resonant Converter Based EV Charging

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ABSTRACT

This paper presents a novel single-stage AC/DC resonant converter designed for electric vehicle (EV) charging applications, addressing the growing demand for efficient, compact, and cost-effective charging solutions. The converter employs resonant techniques to achieve soft-switching, thereby minimizing switching losses, reducing electromagnetic interference (EMI), and enhancing overall efficiency. By integrating the AC-DC conversion process in a single stage, the proposed design eliminates the need for multiple conversion stages, leading to a simpler topology and lower component count. This not only reduces system complexity but also optimizes space, making it particularly well-suited for both residential and public EV charging stations. It is capable of providing stable and efficient power delivery to the EV battery, even under varying load conditions, which is critical for fast and reliable EV charging. The use of resonant circuits also contributes to reduced electromagnetic interference (EMI), ensuring compliance with stringent regulatory standards. The results demonstrate significant improvements in efficiency compared to conventional non-resonant converters, with reductions in both switching and conduction losses. The converter also exhibits robust thermal performance, contributing to longer operational lifespans and reduced maintenance costs. This work highlights the potential of the single-stage AC/DC resonant converter as a viable solution for the next generation of EV charging infrastructure, offering advantages in terms of efficiency, cost, and compactness.

KEYWORDS

AC/DC converter, LLC resonant converter, power factor correction (PFC), zero voltage switching (ZVS).

INTRODUCTION

Electric vehicles (EVs) have emerged as a key solution in the global effort to reduce greenhouse gas emissions, promote energy efficiency, and decrease dependence on fossil fuels. With the rapid growth in EV adoption, the need for efficient, reliable, and cost-effective charging infrastructure has become more critical. Traditional EV charging systems rely on multiple stages of conversion, typically starting with an AC-to-DC conversion, followed by a DC-DC converter for voltage regulation. These multi-stage systems, while effective, present significant challenges in terms of energy loss, increased component count and higher costs. Furthermore, the complexity of these systems increases their size and weight, which limits their applicability in various environments, particularly in residential or compact commercial settings. Additionally, the presence of multiple switching stages can result in higher electromagnetic interference (EMI), requiring additional filtering and leading to potential reliability concerns.

To address these limitations, resonant converters have gained attention as a promising solution. These converters utilize resonant circuits to achieve soft-switching, significantly reducing switching losses, minimizing electromagnetic interference (EMI), and improving overall power conversion efficiency. Resonant converters are particularly well-suited for high-efficiency applications like EV charging, where efficiency and performance are paramount. By using resonant frequencies, these converters can operate at high switching speeds while reducing thermal and electrical stress on components. As a result, resonant converters offer significant improvements in efficiency, reduced heat generation, and lower electromagnetic interference. Furthermore, the inherent soft-switching characteristics of resonant converters can also prolong the lifespan of components by reducing the stress placed on them during operation. Grid-connected PV systems are often deployed at higher penetration levels compared to standalone PV systems due to their reliance on the electric grid for balancing fluctuations in PV output. Solar-powered EV adoption is a key strategy to effectively tackle environmental concerns.

For EV charging applications, resonant converters present a unique advantage due to their ability to handle high-frequency switching with minimal loss, a critical factor in fast-charging scenarios. In addition, resonant converters can be designed to operate over a wide input voltage range, making them adaptable to different grid conditions and ensuring a stable power supply for EV charging, even in regions with fluctuating electrical infrastructure. In this paper, we focus on the development and performance evaluation of a single-stage AC/DC resonant converter specifically designed for EV charging. We explore various aspects of the converter's design, including component selection, topology optimization, and the implementation of control strategies that allow for optimal operation under diverse charging scenarios. We also provide a comprehensive efficiency analysis, comparing the performance of the proposed

converter with conventional multi-stage designs. The experimental results from the prototype demonstrate the practical advantages of the single-stage AC/DC resonant converter, highlighting its superior efficiency, reduced size, and lower EMI levels.

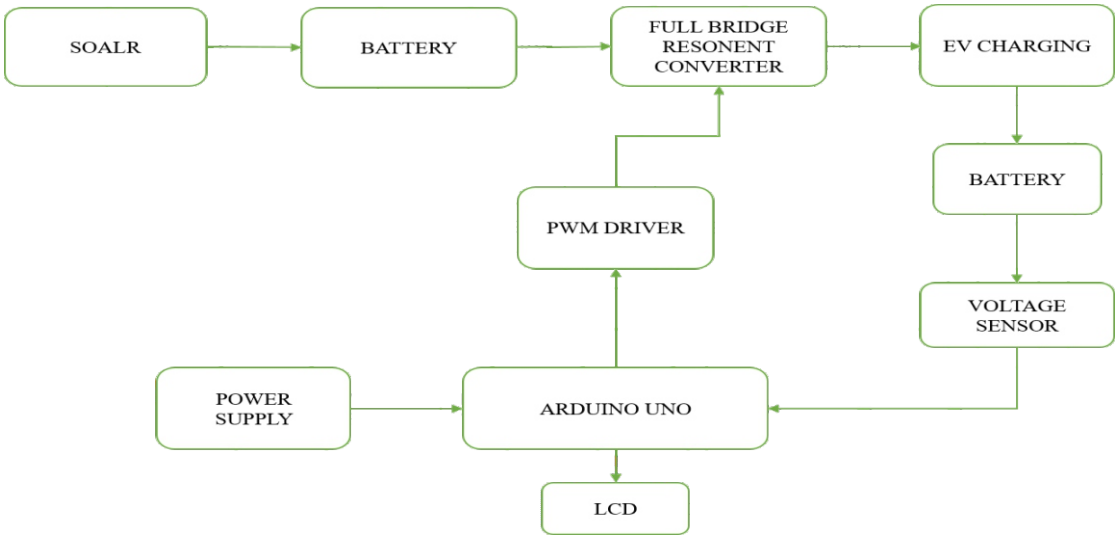


Fig A. Proposed System Description

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ADVANTAGES

A. HIGH EFFICIENCY

The integration of a Full-Bridge Resonant Converter (FBRC) with solar power and battery storage significantly improves the overall efficiency of the system. The FBRC operates with soft-switching techniques, which reduce switching losses and electromagnetic interference (EMI), resulting in a higher efficiency compared to conventional converters. This leads to faster and more efficient EV charging while minimizing energy wastage.

B. SUSTAINABILITY AND RENEWABLE ENERGY USE

By utilizing solar energy as the primary power source, the proposed system reduces dependency on the grid and leverages renewable energy. This not only lowers electricity costs but also contributes to a greener, more sustainable solution for EV charging, aligning with global efforts to reduce carbon emissions and promote clean energy.

C. REDUCED DEPENDENCY ON GRID POWER

The use of battery storage allows the system to store excess energy generated by the solar panels, providing power even during periods when solar generation is low or unavailable (e.g., night time or cloudy weather). This minimizes reliance on the grid, offering energy independence and ensuring continuous power supply to the electric vehicle.

D. SCALABILITY AND FLEXIBILITY

The system is highly adaptable, making it suitable for various applications, from residential installations to commercial EV charging stations. The modular design enables the system to be scaled up or down depending on the power needs, allowing for efficient deployment in different environments.

E. COST SAVINGS AND LONG-TERM INVESTMENT

The integration of solar panels with battery storage and an efficient resonant converter not only reduces the operational cost by utilizing free solar energy but also lowers energy bills over time. While the initial setup cost might be higher, the system offers significant long-term savings, making it a worthwhile investment for residential and commercial users. Many have studied single-stage ac/dc resonant converter topologies that use boost-type PFC circuits and generate a relatively steady dc voltage on the bus capacitor, which is also the input voltage of the resonant tank.

APPLICATIONS

A. ELECTRIC VEHICLE (EV) CHARGING STATIONS

The primary application of the proposed system is in EV charging infrastructure. By using renewable solar energy and battery storage, the system provides efficient, sustainable, and cost-effective charging for electric vehicles. This is particularly useful in locations where reducing grid dependency and promoting green energy is a priority.

B. RESIDENTIAL SOLAR EV CHARGING

The system is ideal for residential use, allowing homeowners to charge their electric vehicles using solar energy. With battery storage, the system ensures that power is available even during non-sunny hours, making it a convenient and eco-friendly solution for private EV owners looking to reduce their electricity bills and carbon footprint.

C. COMMERCIAL AND INDUSTRIAL CHARGING STATIONS

The scalability of the system makes it suitable for large-scale commercial or industrial EV charging stations. Businesses and industries with fleets of electric vehicles can benefit from this system

by charging their vehicles efficiently and sustainably, contributing to a reduction in operational costs and supporting corporate sustainability goals.

D. REMOTE OR OFF-GRID CHARGING SOLUTIONS

In remote or off-grid areas where access to the electrical grid is limited or unavailable, the proposed system can serve as a standalone solution for EV charging. With solar power generation and battery storage, the system can provide a reliable and autonomous charging option, reducing the need for costly grid extension.

E. RENEWABLE ENERGY INTEGRATION IN SMART GRIDS

The proposed system can be integrated into smart grids, where energy management and optimization are key. By combining solar power generation, battery storage, and efficient DC-DC conversion, the system can play a vital role in balancing energy distribution, providing an efficient and sustainable solution for modern energy systems, and contributing to grid stability and energy optimization. The proposed system combines renewable energy generation, efficient power conversion, and intelligent control through the use of solar power, battery storage, Full-Bridge Resonant Converters (FBRC), and microcontroller-based management to create a high-efficiency EV charging solution. By reducing energy wastage, improving charging speeds, and providing flexibility through scalable design, the system provides a sustainable and cost-effective solution for the future of electric vehicle charging infrastructure.

ABBREVIATIONS AND ACRONYMS

BMS-Battery Management System, EMI-Electromagnetic Interference, EV-Electric Vehicle, FBRC-Full-Bridge Resonant Converter, LLC-Inductor-Inductor-Capacitor, MPPT - Maximum Power Point Tracking, PV – Photovoltaic, PWM - Pulse Width Modulation, SOC - State of Charge, SOH - State of Health, V2G -Vehicle-to-Grid, ZVS - Zero-Voltage Switching.

AC/DC STEP-UP ANALYSIS

For an ac/dc converter with unity power factor, assuming that the input voltage us and current is are both sinusoidal, the instantaneous value of the input power pin is given by

$$p_{\mathrm{in}}(t) = u_{\mathrm{s}}(t) i_{\mathrm{s}}(t) = U_{\mathrm{sm}} I_{\mathrm{sm}} (\sin(\omega_{\mathrm{s}} t))^2 \qquad (1)$$

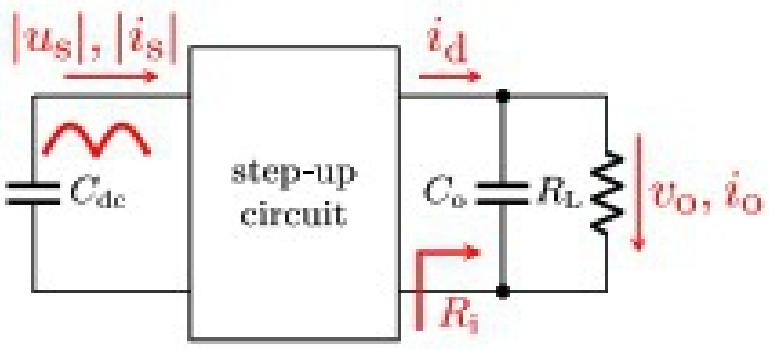


Fig. 1. Step-up converter.

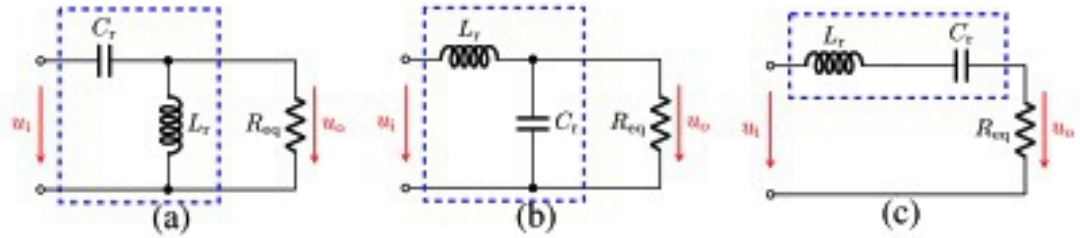


Fig. 2. Different types of LC resonant networks. (a) CL parallel resonance. (b) LC parallel resonance. (c) LC series resonance.

where Usm, Ism, and ωs are the peak value of us and is, and theac angular frequency, respectively. pin varies with the ac input while the output voltage and power change little owing to the output capacitor Co, which stores and releases energy in the ac period if there are not any middle-stage bus capacitors as shown in Fig. 1.Considering that vo, io, and RL are the output voltage, output current, and load resistor, respectively. The current of the secondary diodes id varies with an average value of Io, while vo changes little. In a conducting period, id,avg and Dd are the average value of id, and the duty cycle of the secondary diodes, respectively. The equivalent resistance Ri decides the output power Po.

PROPOSED RESONANT CONVERTER

Using a full-bridge structure as an example, the circuit topology for the proposed LLC resonant converter is shown in Fig. 3. The topology comprises an LC filter with an input ac source us, a rectifier connected to a capacitor Cdc, a full-bridge LLC resonant network, and an output rectifier. The LLC resonant network consists of switches S1–S4, a transformer with resonant.

Moreover, most classical LLC resonant converters usually use the resonance of Cr and Lr1. However, Lm is clamped when Cr and Lr1 resonate, weakening the step-up effect. Thus, the proposed converter uses the resonance of Cr and Lm, and Lm much more important than Lr1. The active involvement of resonance for Lm enables the output voltage to be elevated, which is suitable for the step-up ac/dc application.

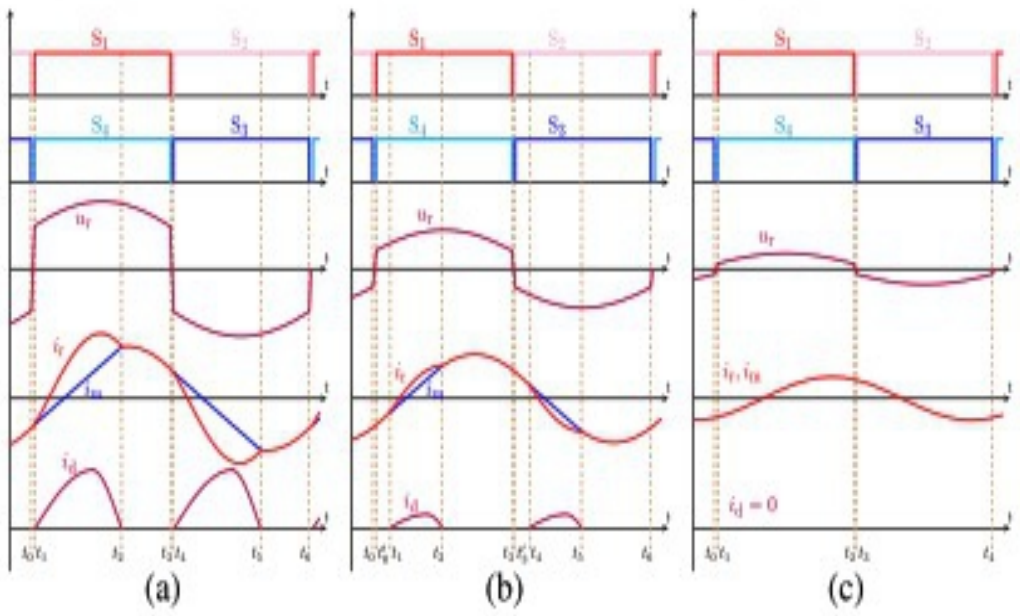


Fig. 3. Operating waveforms of the resonant converter. (a) Input voltage is relatively high (Mode I). (b) Input voltage is relatively low (Mode II). (c) Input voltage is extremely low (Mode III).

Inductor Lr1, Lr2, and Lm, and the resonant capacitor Cr. In this article, by controlling the switching frequency fsw, three control targets can be achieved. First, the output voltage vo should be controlled even if the instantaneous value of the ac input reaches zero periodically. Then, the input current is should be nearly sinusoidal, and the power factor should be close to 1. Moreover, soft switching of all semiconductor switches should be achieved.

Although using an LLC resonant converter to regulate output voltage is not a new concept, the proposed converter goes a step further by not only regulating output voltage but altering various operating conditions to control power and functioning as a PFC directly. This expansion of the capabilities of the LLC resonant converter increases its potential applications because the proposed converter is not only a voltage regulator. Moreover, most classical LLC resonant converters usually use the resonance of Cr and Lr1. However, Lm is clamped when Cr and Lr1 resonate, weakening the step-up effect. Thus, the proposed converter uses the resonance of Cr and Lm, and Lm is much more important than Lr1. The active involvement of resonance for Lm enables the output voltage to be elevated, which is suitable for the step-up ac/dc application.

The duty cycle of the switches is 0.5. Assuming that the diodes and switches are ideal with a fixed output voltage and a nonzero constant input voltage in a switching period, the converter has three operating modes in an ac period. It operates in Mode I with a relatively high input. The operating

waveforms are presented

EXPLANATION OF SIMULATION DIAGRAM & OUTPUT

In a single-stage AC/DC resonant converter, the output voltage, current, and power depend on various factors, including the design of the converter, the load conditions, and the efficiency of the converter. Below is a breakdown of how these parameters are determined and their relationship in a typical converter system. The output voltage of the AC/DC resonant converter is the regulated DC voltage delivered to the load after the AC input is converted and rectified. The output voltage is typically controlled by the converter's design, including the choice of resonant components and the feedback mechanism for voltage regulation. For a DC output, the voltage is determined by the design of the converter and the control strategy, which typically involves adjusting the switching frequency and modulation techniques to maintain a stable output voltage despite variations in input or load.

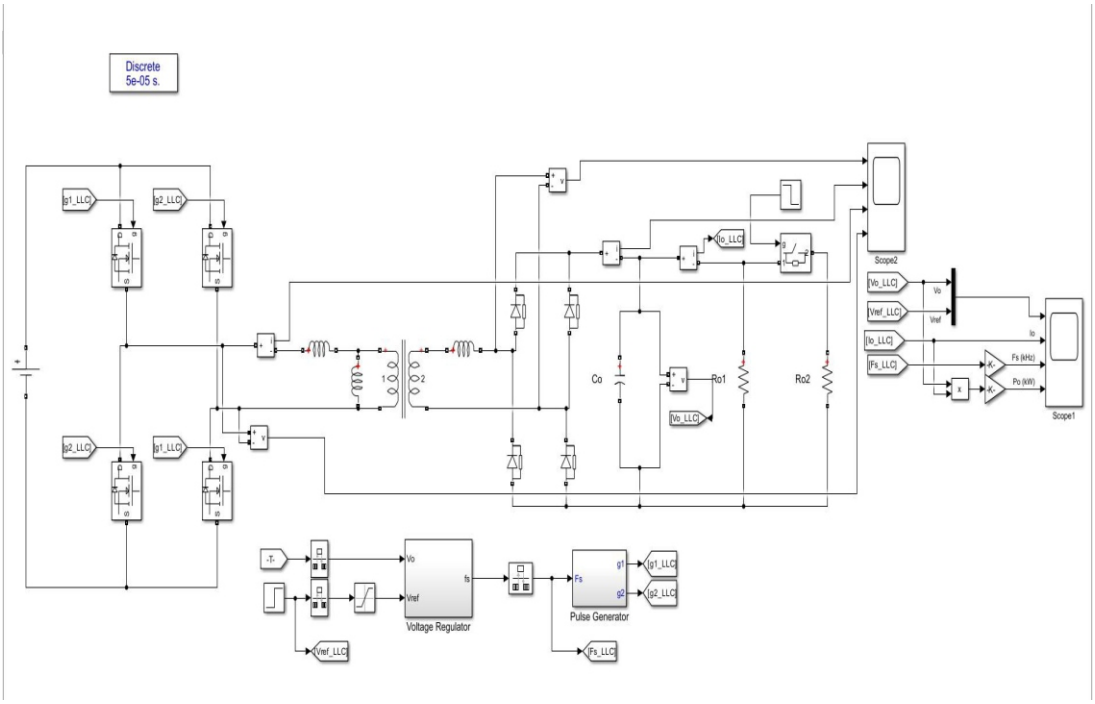
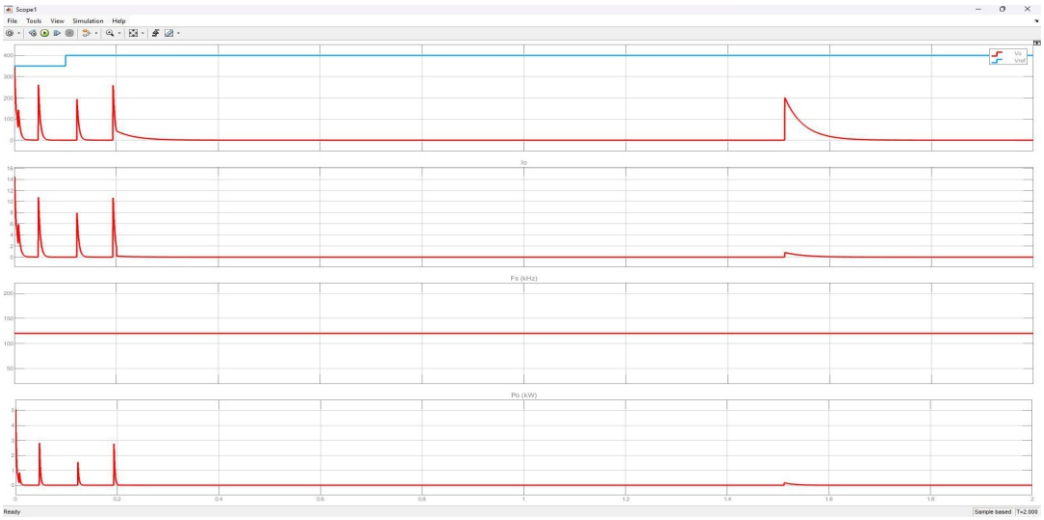
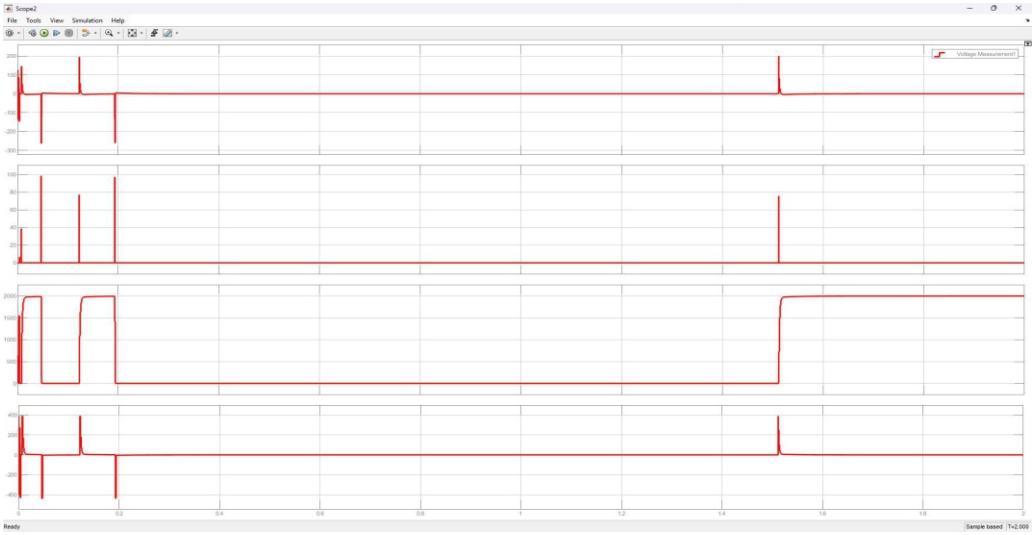


Fig. 4. Proposed resonant converter

OUTPUT VOLTAGE, CURRENT, POWER WAVEFORM



CONVERTED VOLTAGE, CURRENT, POWER WAVEFORM



CONCLUSIONS

The proposed system for Electric Vehicle (EV) charging, which integrates solar power, battery storage, and a Full-Bridge Resonant Converter (FBRC), offers a highly efficient, sustainable, and flexible solution for the future of EV charging infrastructure. By utilizing solar energy as the primary power source, the system significantly reduces dependency on the grid and helps mitigate the environmental impact associated with traditional fossil-fuel based power generation. The battery storage system ensures a continuous and reliable power supply, even during periods of low solar generation, making the system adaptable to varying conditions and capable of providing 24/7 charging support. The FBRC, with its

resonant switching technology, maximizes energy conversion efficiency and minimizes power losses, ensuring fast and effective charging while reducing the overall size and complexity of the converter. The integration of an Arduino microcontroller and PWM-based control allows for precise real-time monitoring and adjustment of the charging process, optimizing the power delivery to the EV battery and ensuring safe and efficient operation. This system is highly scalable, catering to both residential and commercial applications, and offers a cost effective alternative to traditional multi-stage charging systems. Furthermore, by reducing energy wastage, improving charging times, and leveraging renewable solar energy, this system contributes to a greener, more sustainable future. Overall, the proposed design presents a robust solution that aligns with global efforts to promote clean energy and accelerate the adoption of electric vehicles, making it an essential component of the evolving EV charging infrastructure.

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Chapter 27
Integrated PV Based SEPIC-Cuk Converter for EV Charging Station Applications

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ABSTRACT

Electric Vehicles (EVs) provide an environmentally sustainable mode of transportation; however, their widespread adoption remains limited due to insufficient EV charging infrastructure, prolonged charging durations, and grid instability during peak demand periods. This study proposes a high-efficiency, high-gain DC-DC converter paired with a solar PV-based EV charging station control algorithm to address these challenges. Fast-charging stations, particularly ultra-fast charging facilities, impose significant stress on electrical grids, leading to potential overloads during peak hours, unexpected power outages, and voltage dips. To mitigate these issues, a novel hybrid DC-DC converter is developed by integrating SEPIC and Cuk converter architectures. This design offers a wide conversion range, minimized voltage stress, and superior efficiency, effectively addressing the intermittent nature of solar PV energy. To optimize performance, the Ant Lion Optimization (ALO) algorithm is employed to fine-tune the Proportional-Integral (PI) controller gains, ensuring precise frequency and voltage regulation. Simulations conducted using MATLAB demonstrate the effectiveness of the proposed EV charging system, achieving an impressive accuracy rate and showcasing enhanced system performance.

KEYWORDS

SEPIC- Cuk converter, Electric Vehicle, Photovoltaic System, Ant lion optimized PI controller, Pulse Width Modulation (PWM)

INTRODUCTION

With the increasing demand for clean energy and the necessity to overcome the limitations of fossil fuels, electric vehicles (EVs) have gained significant attention across various nations. The primary goals of EV adoption include minimizing air pollution, reducing reliance on fossil fuels, and improving energy security. However, these objectives are fully realized only when EVs are integrated with renewable energy sources (RES). Among the various RES options, solar photovoltaic (PV) systems are widely preferred for EV charging due to their abundant availability in nature and zero carbon emissions.

High-gain DC-DC converters are employed to optimize the output voltage over a broader range since the low power output of PV systems is insufficient to meet energy demands. The increasing need for efficient charging stations capable of supporting high-power, ultra-fast charging arises from the larger battery capacities and extended driving ranges of modern EVs. Despite advancements, PV integration in EV charging stations is still a minor contributor to their power supply in many studies. Considering the rising demand for fast charging during daytime hours, the rapid evolution of PV technology enhances energy utilization during peak periods with sufficient daytime power generation.

Fast-charging stations significantly reduce the time required for an EV charging cycle. Additionally, the widespread deployment of fast EV charging infrastructure in urban and residential areas helps mitigate range anxiety for EV users. However, Level 3 charging exerts substantial stress on utility grids, necessitating the use of high-power charging rates for short durations. The current grid infrastructure is inadequate to support the desired charging rates. Thus, achieving fast charging rates requires both advancements in charging technologies and enhancements in grid capacity. Drawing large amounts of power from the grid during peak periods would also lead to higher utility costs, increasing system expenses.Grid-connected PV systems are often deployed at higher penetration levels compared to standalone PV systems due to their reliance on the electric grid for balancing fluctuations in PV output. Solar-powered EV adoption is a key strategy to effectively tackle environmental concerns. However, the low voltage output of PV modules necessitates the use of suitable DC-DC converters to achieve higher voltage levels.

A Single-Ended Primary-Inductor Converter (SEPIC) is a DC/DC voltage regulator capable of stepping up, stepping down, or maintaining the input voltage. The benefits of SEPIC converters include a stable output voltage, continuous input current, efficiency levels ranging from 90–95%, non-inverted output, and resilience to short circuits. A Ćuk Converter is a DC/DC voltage regulator that utilizes a capacitor as the main energy reservoir for transferring power. It can effectively reverse the output voltage polarity relative to the input and efficiently boost or reduce voltage levels. The primary benefits of the Ćuk converter include uninterrupted input and output currents, minimal electromagnetic disturbance (EMI) due to the incorporation of input and output inductors, and superior efficiency, making it well-suited for a wide range of power management applications.

PROPOSED SYSTEM DESCRIPTION

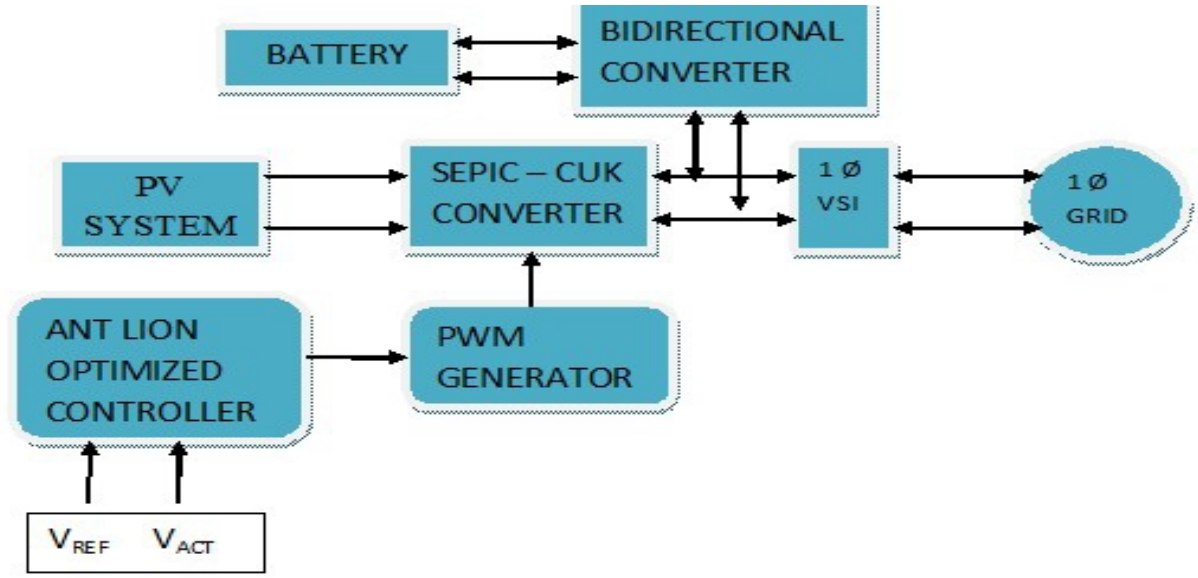


Fig.1 Block diagram of proposed system.

With the decline of fossil fuel reserves and the pressing need to curtail carbon emissions to mitigate the impacts of global warming, the concept of photovoltaic (PV)-powered electric vehicles (EVs) is gaining significant traction. These vehicles promote decarbonized energy production and sustainable transportation solutions, making them highly relevant in today's context. However, due to fluctuations in temperature and variations in solar irradiance, electricity generation from PV systems is inherently inconsistent. The adoption of solar-powered EVs is therefore pivotal in addressing environmental challenges effectively. Since the output voltage of PV modules is relatively low, a suitable DC-DC converter is required to step up the voltage to the necessary levels.

The PV system captures solar energy and transfers it to the battery, which stores the power after the PV source. Any excess energy is directed to the Boost-Cuk converter, which provides DC-to-DC voltage to the single-phase Voltage Source Inverter (VSI). The VSI then delivers the output power to the LC filter, and the system is monitored by the single-phase grid. During night-time, excess energy from the proposed sources is processed, and the Ant Lion Optimized PI Controller receives both the reference and actual voltage. This controller regulates power delivery to the PWM generator, which produces pulse-width modulation (PWM) signals and supplies them to the SEPIC-Cuk converter. The reference and actual power values managed by the PI controller are similarly passed to the PWM generator, which transforms them into pulses for the single-phase VSI. By utilizing an appropriate converter, the output from the PV panel can be significantly enhanced, with the converter’s amplified output being fed into the single-phase VSI to produce an inverted output.

PROPOSED SYSTEM MODELLING

A. PV System

In this solar energy generation process, insufficient variably active particles are captured at the p-n junction. Relative to the band gap, this field utilizes the highest energy photons. A single transistor is employed to construct analog devices that are frequently used to simulate photovoltaic (PV) cells, offering an improved balance between accuracy and practicality. The associated diagram is shown in Figure 2. Prepare Your Paper before Styling

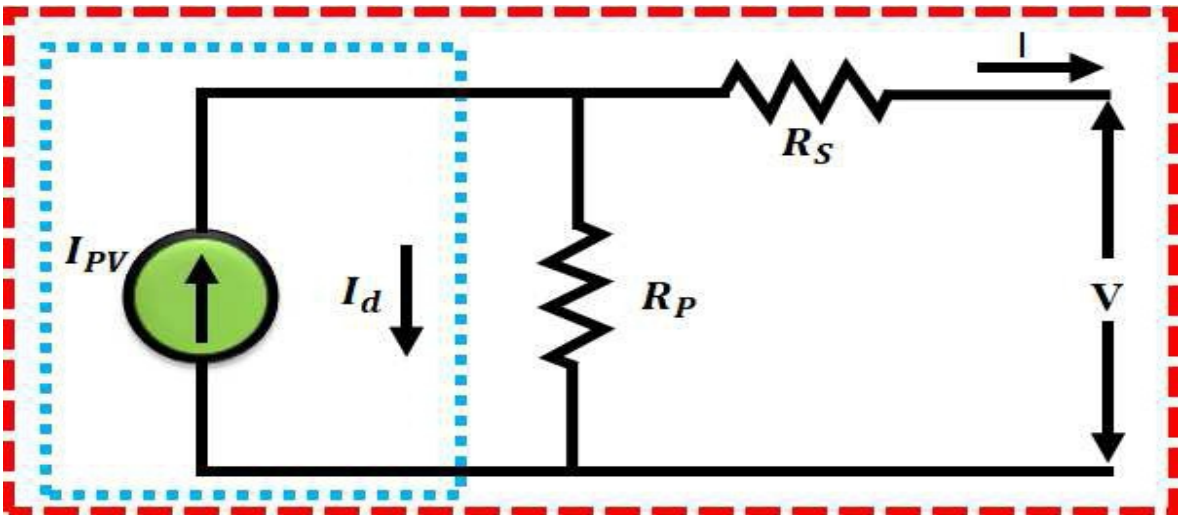


Fig.2 Circuit diagram of PV system.

$$I = I_{SC} - I_0 \left(eq(V + IR_S)kT^{-1} \right) - (V + IR_S R_P) \quad (1)$$

Thus, the performance of the solar system is achieved, and from equation (1), the generated power and the input power are compared. This equation defines the current output by accounting for the voltage and shunt resistance.

A. Analysis of Cuk Converter

The unregulated output voltage from the PV panel is converted into a stabilized voltage using the Cuk converter, as illustrated in Fig. 3. Energy transfer in the Cuk converter is facilitated by the capacitor, in contrast to conventional converters where it relies on the inductor. This design ensures a continuous input current. The Cuk converter, a type of chopper circuit, produces an output voltage that is negative relative to the common terminal and operates in continuous conduction mode [9].

In Fig. 3, when switch S1S_1S1 is activated (ON), diode D1D_1D1 is reverse-biased, and the currents through inductors L1L_1L1 and L2L_2L2 gradually increase, supplying power to the load. Conversely, when S1S_1S1 is deactivated (OFF), the diode becomes forward-biased, allowing capacitor C1C_1C1 to discharge in preparation for the next cycle. The DC output voltage of the Cuk converter, expressed in terms of the duty cycle ratio, is provided by Eq. (2)

$$V_{cuk}=\left(\frac{d_1}{1-d_1}\right)V_{pv} \quad (2)$$

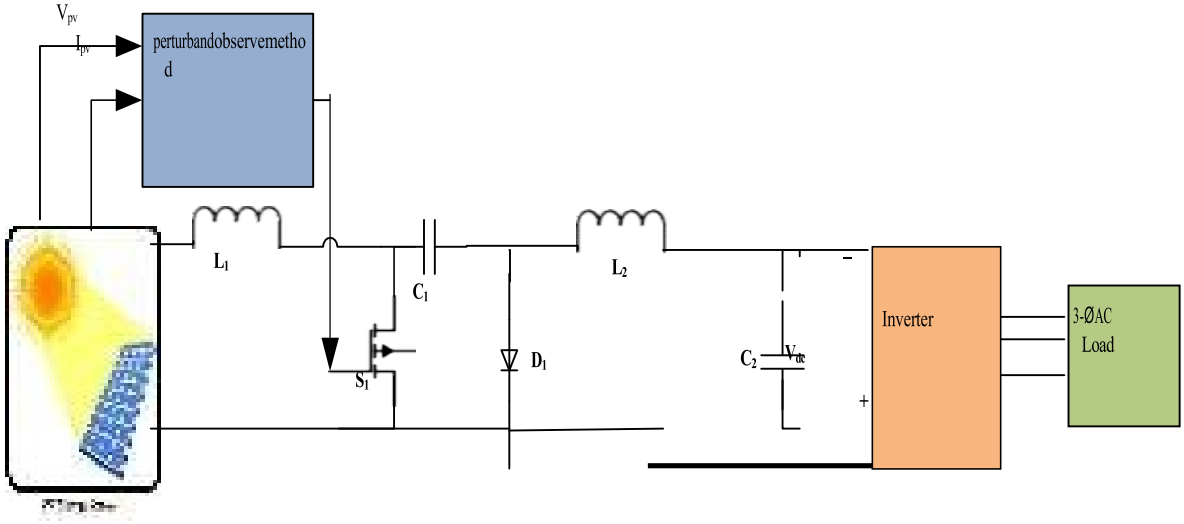


Fig.3 Circuit diagram of CUK Converter.

B. Analysis of the SEPIC converter

The rectified output voltage from the wind energy system is supplied to the Single-Ended Primary Inductor Converter (SEPIC) to achieve the desired voltage level required to meet the load demand, as illustrated in Fig. 6. The SEPIC converter, fundamentally a type of chopper, can produce an output voltage either higher or lower than the input voltage. In this case, the step-up mode is utilized to align with the load profile. The DC output voltage of the SEPIC converter, expressed in terms of the duty cycle ratio, is provided in Eq. (5) [10,11].

C. SEPIC – CUK Converter

A SEPIC (Single-Ended Primary-Inductor Converter) - CUK converter is a type of DC-DC converter that can step up or step down the input voltage. It combines two popular converters: the SEPIC and the CUK converters, which can both provide non-isolated voltage conversion. These converters are used in applications where the input voltage can vary and a stable output voltage is required. The schematic representation of the proposed integrated Cuk-SEPIC converter is illustrated in Fig.3 and 4 This innovative integrated converter is developed by reconfiguring the diodes (D1, D2) in the Cuk and SEPIC converters and utilizing the output inductor (L2) of the Cuk converter within the SEPIC converter. This approach streamlines the complexity of the power system circuitry while reducing both cost and physical dimensions. The converter functions as a three-port device: the first port connects to the input PV source, the second port interfaces with the wind source, and the third port serves as the output, providing input to the inverter for delivering three-phase AC power to the standalone system.

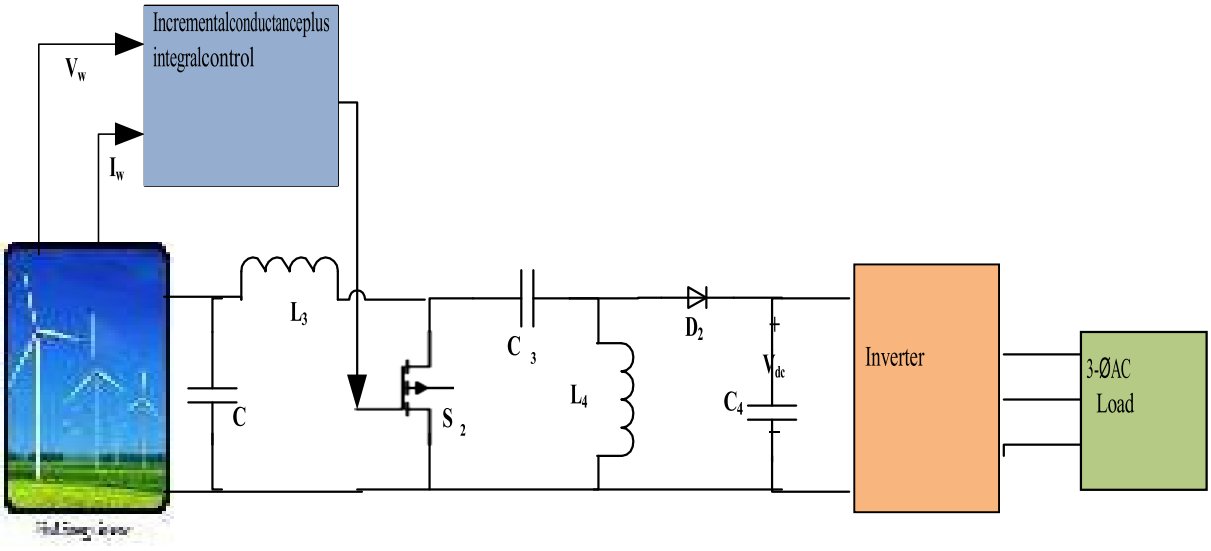


Fig.4 Circuit diagram of SEPIC Converter

As per the reconfiguration outlined above, each converter can operate either simultaneously or independently, depending on the availability of the PV and wind sources. The DC link voltage, Vdc V_{dc}Vdc, for the proposed converter is the combined output of the two converters, as expressed. This voltage is regulated by adjusting the duty cycles d1d_1d1 and d2d_2d2 of the Cuk and SEPIC converters, respectively. These duty cycles are determined using the equations provided in Eq. (2) through duty ratio control.

$$V_{dc}=\left(\frac{d_1}{1-d_1}\right) V_{pv}+\left(\frac{d_2}{1-d_2}\right) V_{wind} \quad (2)$$

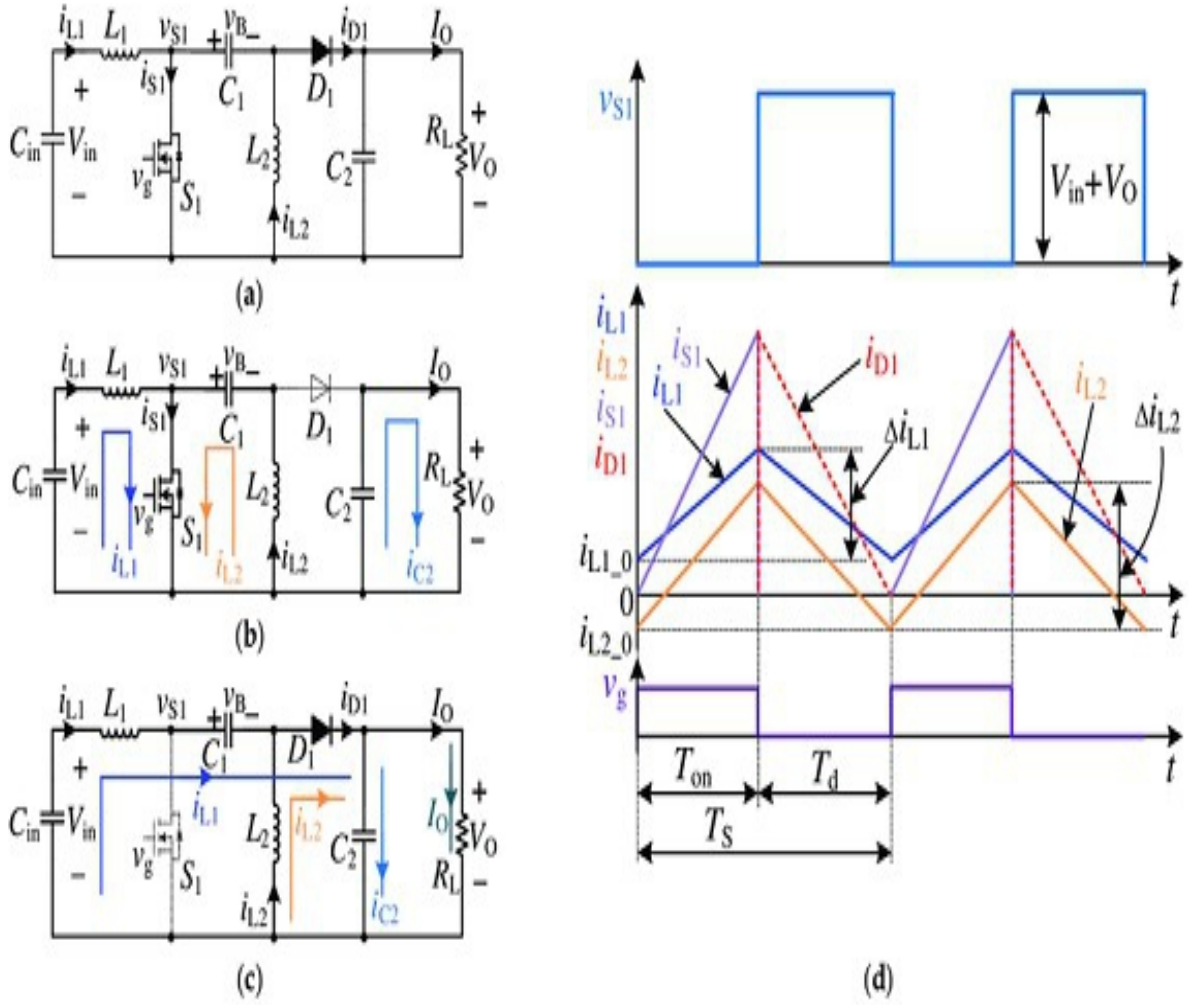


Fig.5 Mode of operation of Converter

D.Ant Lion Optimized PI Controller

The ant lion optimization (ALO) technique demonstrates superior convergence, high efficiency, and faster computation compared to particle swarm optimization (PSO) and grey wolf optimization (GWO). Consequently, it is utilized to determine the optimal PI gain values for frequency and voltage control. The ALO method is employed to optimize the PI gains of the frequency and voltage controllers. This approach mimics the natural interaction between ants and ant lions in a trap. Ants exhibit random movement while foraging for food in the wild and this behavior can be effectively modeled as:

Here, t represents the random walk period, cscomputes the critical sum, intermix denotes the iteration count, and r(t)r(t)r(t) is a predefined function. To assess the performance of each ant and ant lion, a fitness function is applied, and the results are stored in a matrix, as shown in Eq. (3).

$$X_1=\frac{X^1_{-x_1}}{d^1_{-x_1}}\text{-}(d_1\text{-}c_1)+c_1\ ) \quad (3)$$

The elite ant lion is considered the most optimal or fittest. Each ant randomly moves around the elite ant lion while also interacting with another ant lion selected through the roulette wheel mechanism. This behavior is mathematically represented as:

$$ANT_t=\frac{R_A+R_E}{2} \quad (4)$$

The optimal ant lion position is designated as FG, representing the best solution, and it significantly influences the movement of all ants. Additionally, FH refers to an ant lion selected through the roulette wheel mechanism, as expressed in Equation (4).

E. Single Phase VSI

A specific type of DC-to-AC inverter, known as a single-stage inverter, converts DC input power into a single-phase AC output at a specified voltage and frequency. There are two primary types: Voltage Source Inverters (VSI) and Current Source Inverters (CSI). A VSI converts constant DC input power into AC output power, where the inverter's terminal voltage remains steady while the output current varies based on the load impedance &freight impedance

RESULTS AND DISCUSSION

In this stage, MATLAB is utilized to simulate the integrated PV system for EV applications. The specifications for the SEPIC-Cuk converter are provided in Table I.

TABLE I. PARAMETERS SPECIFICATION OF SEPIC-CUK CONVERTER

PARAMETERS	SPECIFICATION
Inductance L	1.5Mh
Capacitance C_1	4.5 µF
Capacitance C_2	23 µF
Capacitance C_3	2250 µF
Resistance R	120 Ω

The solar board temperature amplitude is shown in Fig. 4. It has 25°at initial and increases and maintains the constant at 35°

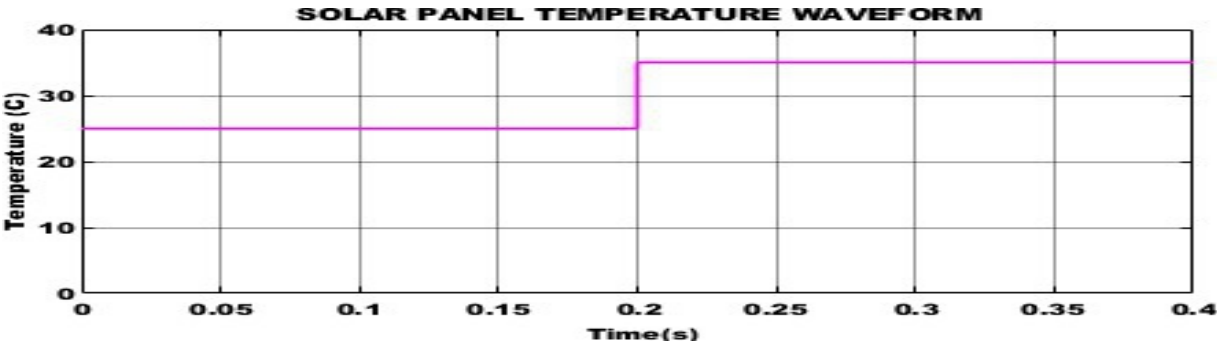


Fig.6 Solar Panel Temperature Wave form

The solar board irradiance waveform is shown in Fig. 5. It maintains the constant value at 800 Wsq.m and increases from 0.2s and maintains the constant value at 1000 Wsq.m

Fig. 6, it demonstrations the solar piece voltage amplitude it has 45V and increases from 0.2S after it has maintains the constant value at 60V.

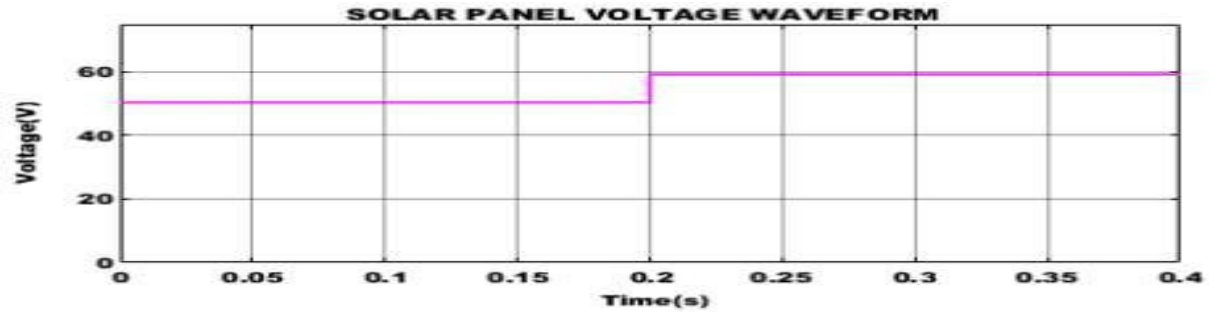


Fig.7 Solar panel voltage wave speed

PV panel existing amplitude demonstrations in Fig. 7 it decrease from 9A and it gets maintains the constant value at 2A.

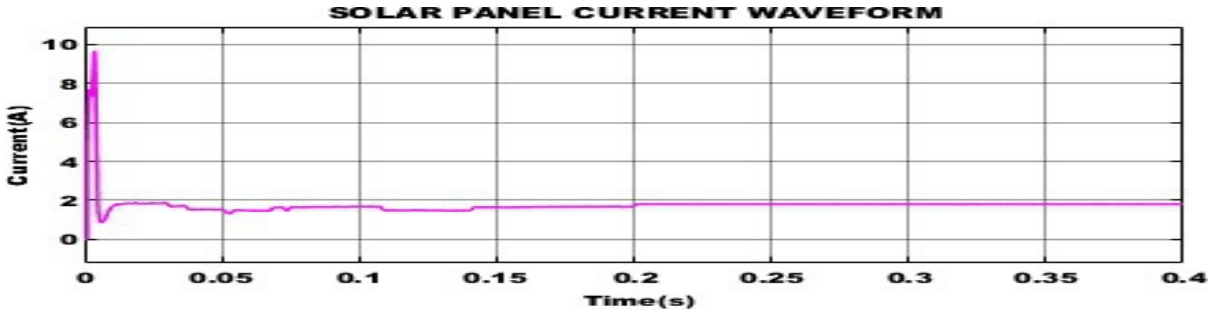


Fig.8 Solar panel current wave form

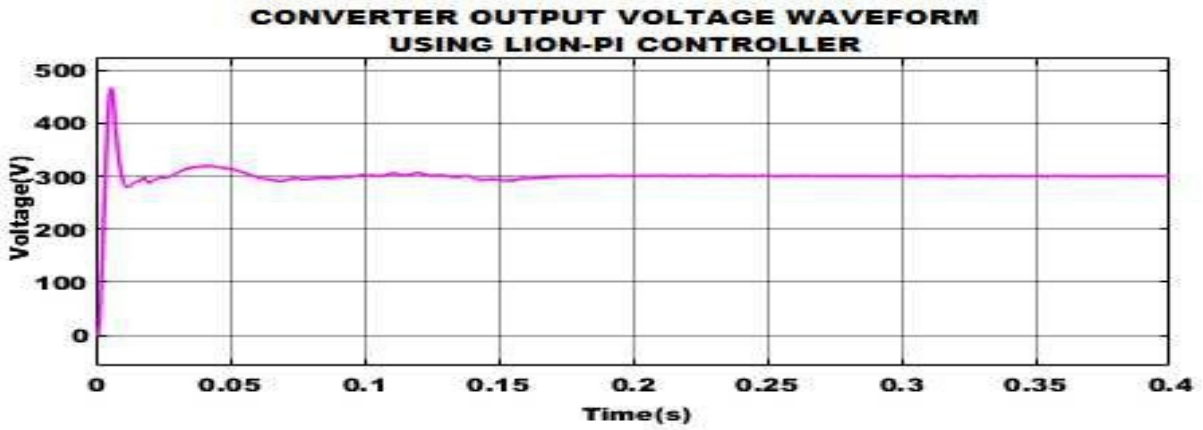


Fig.9.Converter output voltage Wave level using Lion-PI controller

The batterySOC waveform maintains the constant value at 65%s is exposed in Fig. 11.

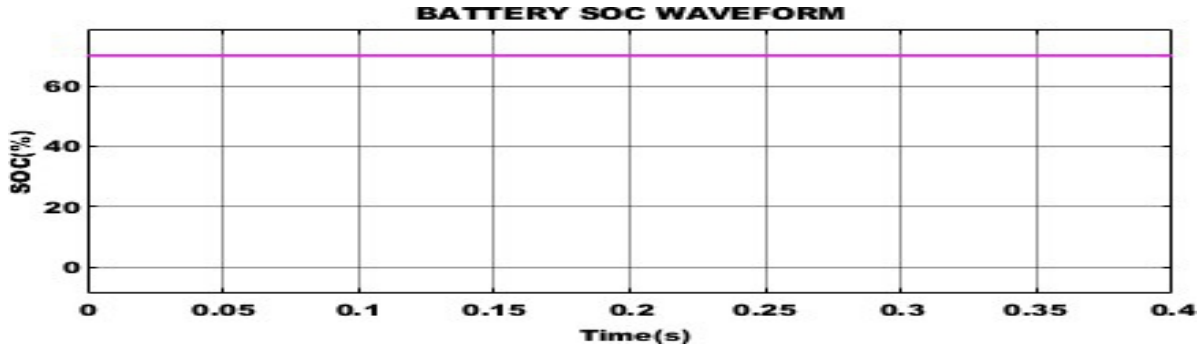


Fig.10 Battery SO C waveform

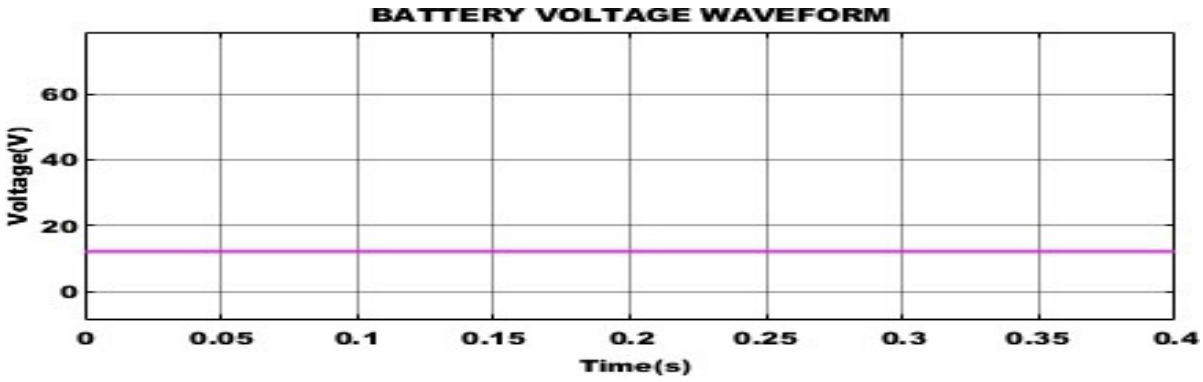


Fig. 11 Battery voltage wave form

Battery voltage amplitude is revealed in Fig. 12 it has continue the constant at 18V

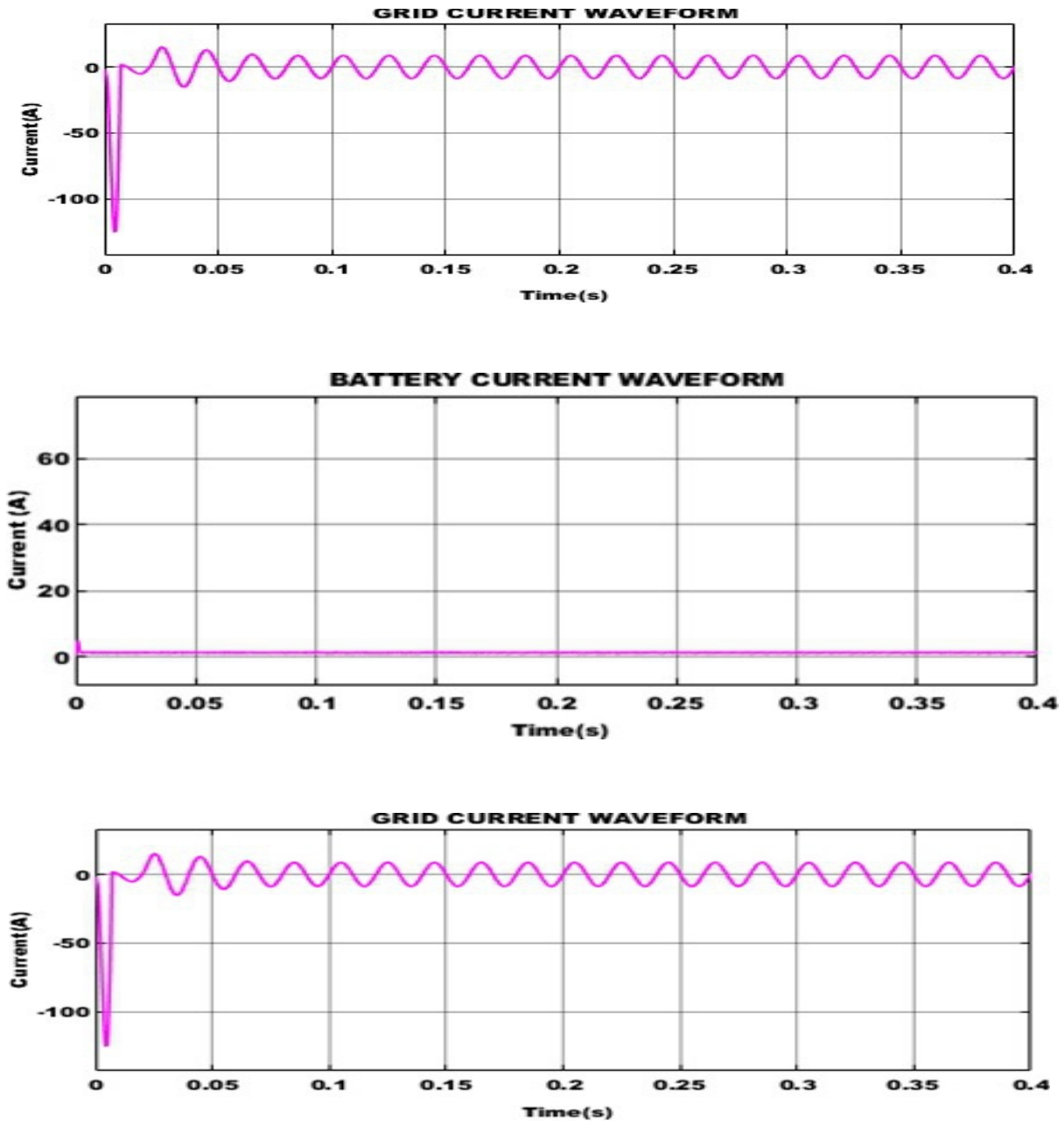


Fig.12 Battery Current wave form

It keeps the constant value of 0A.The Grid power amplitude is upholds the continuous value as 200Vis exposed in **Fig. 13**

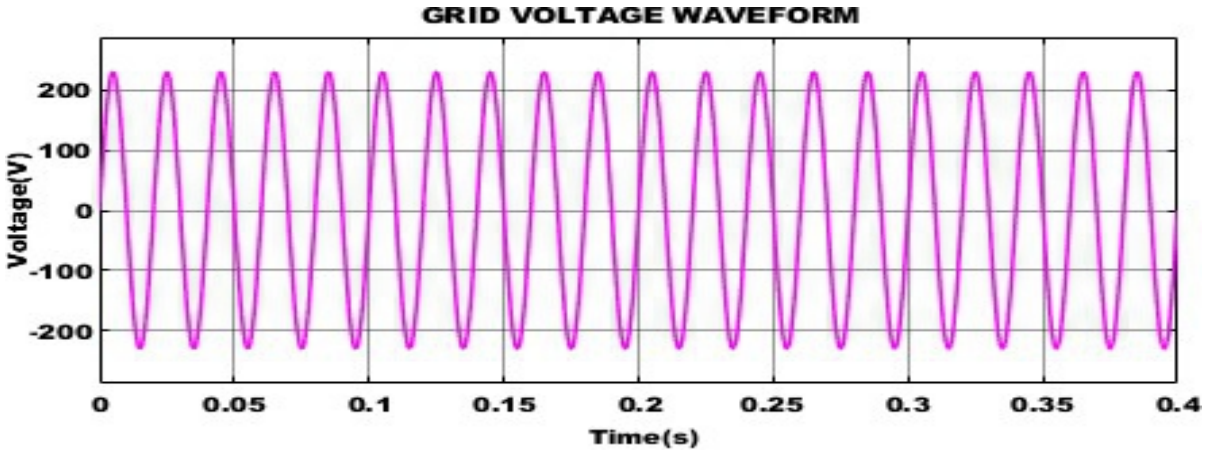


Fig. 13 Grid voltage wave form

A grid Current Waveform is increases form the negative value and it continues the continuous worth as 0A.The reactive power waveform develops from 0 to 800VAR after a dip, and then returns to a continuous value of 0VAR, as illustrated in Fig. 14

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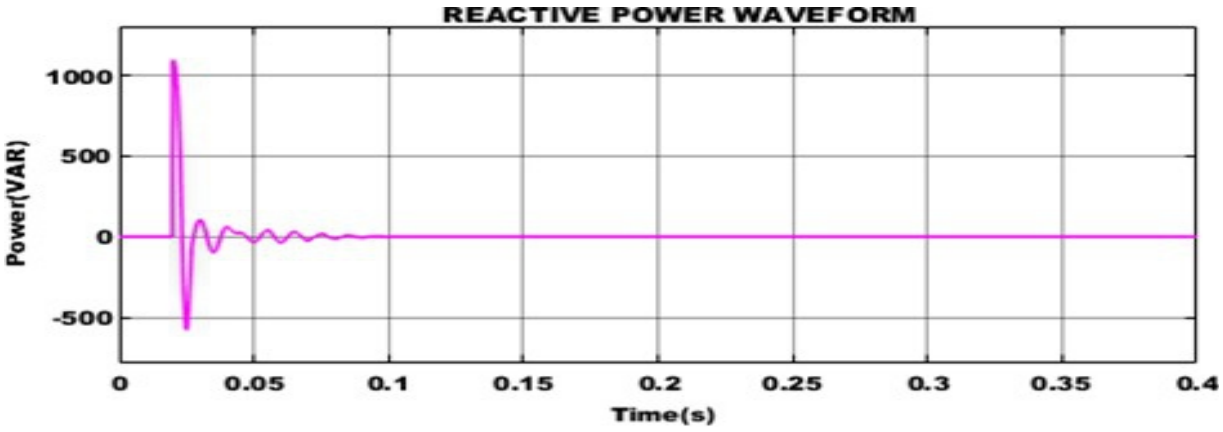


Fig. 14 Reactive Power voltage wave form

The real power amplitude is exposed in Fig. 17, it decreases from 0W and increases from negative value after maintains the constant value 1500W Fig.14 Reactive power wave form

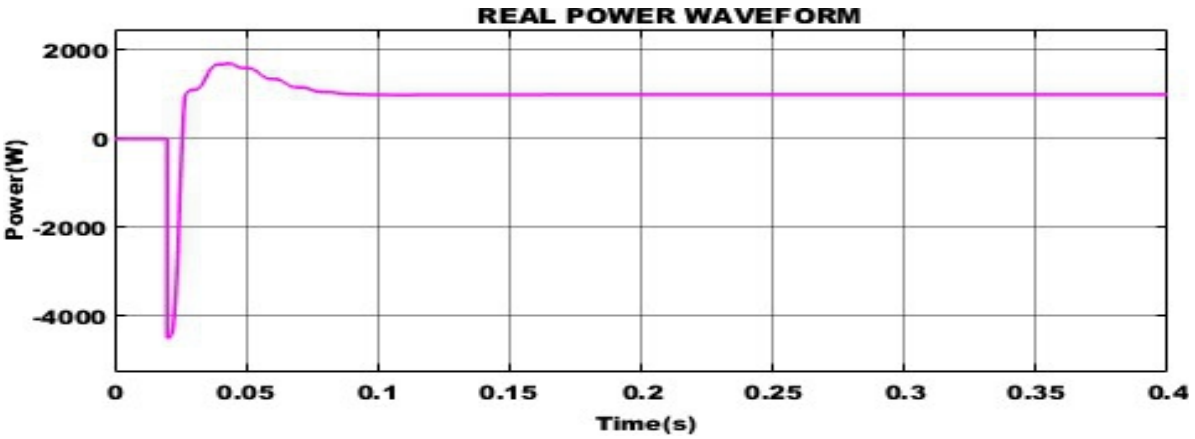
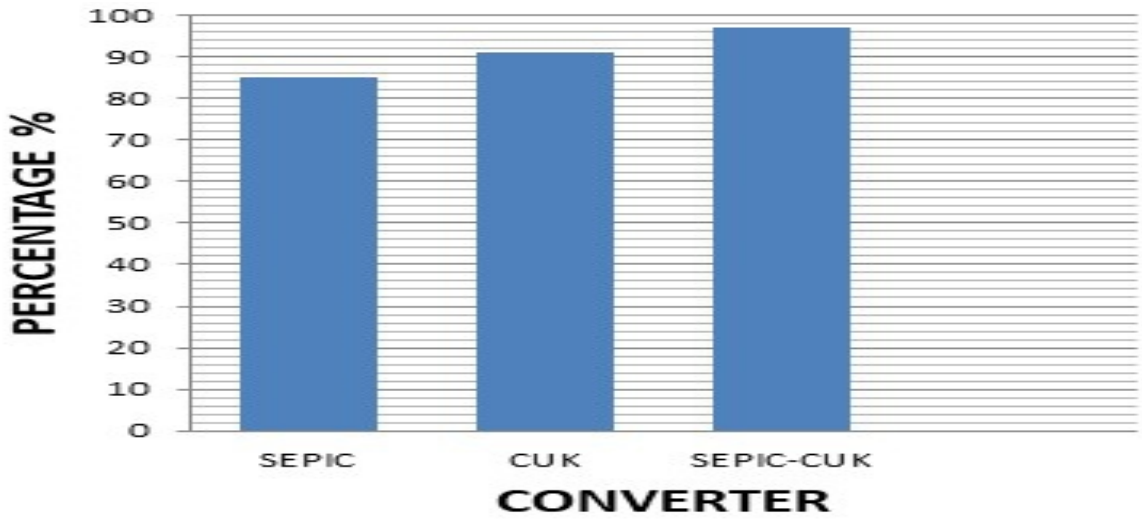


Fig.15 Real power wave form

A grid Current Waveform is increases form the negative value and it continues the continuous worth as 0A is shown in Fig. 15.The contrast of correctness standards of the converters is registered in Fig. 18 as 89%, 91% and 97% for Boost, Cuk and Boost-Cuk converters correspondingly.



CONCLUSIONS

In instruction to significantly advance the performance of the PV organization, which serves as the main basis of power source for the planned EV accusing position, a unique Ant lion PI controller was created to regulator the proposed converter. The growth of an optimum control method for grid linked solar EV indicting positions aims to enhance EV acceptance while minimizing reliance on the grid. The fundamental irregularity associated with PV is eliminated by combining the SEPIC-Cuk converters, which results in a special DC to DC translator that combines the amazing advantages of high change variety, decreased voltage stress, and great competence. The SEPIC-Cuk converters accuracy comparison is 97%.

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Chapter 28

Ad-Hoc Network-Enabled IoT-Based Monitoring for Power Grid and Inverter Harvesting in Smart Cities

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ABSTRACT

Smart water management in supply systems is essential to optimize the use of water resources and the quality of service. In this context, the Internet of Things (IOT) can be a valuable tool, as it enables the integration of multiple technologies, storing and analyzing data from different sources in real-time, and extracting contextual information. . This proposed system consists of microcontroller interfaced with three sensors namely toxic gas sensor, turbidity sensor and ultrasonic sensor. The toxic gas sensor detects the toxic gases in the water. The system aims to ensure water purity through continuous monitoring and to distribute water efficiently according to users' needs. By leveraging IOT sensors and automated controls, the project seeks to address inefficiencies and corruption in current manual and decentralized systems, providing a reliable, transparent, and equitable solution to meet the growing demands of urban populations. To develop an advanced water distribution system using IOT technology to automate and optimize the management of water resources.

KEYWORDS

Smart Water Management; Internet of Things (IoT); Water Quality Monitoring; Automated Distribution System; Resource Optimization

INTRODUCTION

Water is an essential resource for sustaining life, supporting agriculture, industry, and energy production, as well as maintaining ecological balance. However, rapid urbanization, population growth, and climate change are placing increasing pressure on existing water resources, making efficient management and monitoring crucial. Clean and safe water, while vital for public health, is increasingly

under threat due to contamination, pollution, and infrastructure issues such as leaks and water loss.The challenge is further complicated by the need to monitor water quality and maintain an effective distribution network across vast geographic areas, which requires constant surveillance and data-driven decision-making. The traditional methods of water quality monitoring and leak detection, while useful, are often limited in terms of scope, real- time accuracy, and response times. There is a growing need for a more sophisticated, automated, and real-time approach that can integrate a wide range of sensors, data analytics, and predictive modeling to ensure the safety, efficiency, and sustainability of water resources.

The proposed water quality monitoring and leakage detection system aims to address these challenges by leveraging the latest advances in Internet of Things (IoT) technologies, machine learning, and sensor networks. By utilizing a network of advanced IoT-enabled key features of this system is its ability to predict potential contamination events before they escalate into public health risks By analyzing historical data, the system can recognize correlations between specific water quality indicators and past contamination events. This predictive capability allows operators to take preventive measures, such as adjusting treatment processes or closing off affected sections of the water distribution network, before the issue becomes more severe. Additionally, the system provides real-time alerts and notifications when water quality parameters deviate from predefined thresholds, ensuring that operators are immediately informed of any issues. The integration of automated alerts also ensures that timely interventions are made, reducing the potential for harm to public health. Alongside water quality monitoring, the proposed system incorporates advanced leakage detection technologies, which are vital for minimizing water loss and reducing infrastructure maintenance costs. Acoustic sensors, which pick up unique sound signatures associated with leaks, are placed along pipelines to detect leaks in real time. These sensors analyze the frequency and intensity of the sound waves generated by leaks, distinguishing them from normal operational sounds. In parallel, pressure monitoring devices track water pressure levels across the distribution network.

Sudden drops in pressure can indicate a leak or burst pipe, and when correlated with acoustic data, the system can pinpoint the exact location of the issue. This approach reduces the need for extensive excavation and helps prioritize repairs, improving the efficiency of maintenance operations. In addition to its water quality and leak detection capabilities, the system also integrates water level monitoring, ensuring that the water supply remains consistent and that disruptions due to low water levels are prevented. Modular nature of the system allows additional sensors to be added as needed, making it possible to expand the monitoring network in response to changing water management requirements. The system's cloud-based architecture also ensures that data can be stored and analyzed at scale, making it Suitable for managing large datasets generated from numerous sensors located across vast geographic areas. The system's scalability also means that it can be adapted to different environmental conditions, from urban

areas with complex infrastructure to more remote rural settings where water sources may be more susceptible to contamination. Incorporating machine learning algorithms enables the system to not only detect current problems but also to forecast future trends.

For example, the system can analyze seasonal patterns, such as increased agricultural runoff during heavy rainfall periods, and prepare for potential contamination events based on historical data. This ability to forecast future events based on past trends provides an additional layer of proactive management, ensuring that water treatment processes are adjusted according to real-time conditions.

The system also includes a user-friendly interface that allows operators to monitor real- time data, view trends, and assess the overall system status. Interactive dashboards provide clear visualizations of water quality parameters, leak locations, and Public access to water quality data also builds trust between water management authorities and the communities they serve, empowering individuals to take an active role in safeguarding water resources. Sustainability is a key consideration in the design of this system. By minimizing water loss through effective leakage detection, optimizing water treatment processes, and reducing chemical treatment costs, the system contributes to more sustainable water resource management practices.The targeted approach to water treatment, enabled by real-time data, reduces the need for broad, blanket chemical applications, thereby minimizing the environmental impact of water treatment processes. The system's ability to detect and address potential issues proactively also ensures that water resources are managed efficiently, reducing waste and improving the resilience of water distribution networks.

In conclusion, the proposed water quality monitoring and leakage detection system represents a forward-thinking solution to the growing challenges of water resource management. Through its integration of IoT technologies, machine learning, and advanced sensor networks, the system ensures real-time, accurate monitoring of water quality and infrastructure conditions.

INTERNET OF THINGS

The Internet of Things (IoT) is a network of goods that include electronics, software, actuators, and connectivity, allowing these devices to connect, interact, and exchange data The definition of the Internet of Things has changed as a result of the convergence of several technologies, including real-time analytics, machine learning, inexpensive sensors, and embedded systems.

The Internet of things is made possible by embedded systems, wireless sensor networks, control systems, automation (including home and building automation), and other conventional disciplines.

WORKING PROCESS

An Internet of Things (IoT) ecosystem is made up of web-enabled smart devices that employ embedded computers, sensors, and communication gear to gather, communicate, and act on environmental data. By connecting to an IoT gateway or other edge device, which either sends data to the cloud for analysis or analyzes it locally, IoT devices exchange the sensor data they gather. These gadgets converse with other similar devices on occasion, acting on the data they exchange.

Although individuals may engage with the devices to set them up, give them instructions, or retrieve the data, the gadgets accomplish the majority of the job without their help. These web-enabled devices' connection, networking, and communication protocols are primarily determined by the particular IoT.

EXISTING SYSTEM

Existing systems for water quality monitoring and leakage detection encompass a variety of technologies and methodologies aimed at ensuring safe and efficient water management. Traditional water quality monitoring relies on manual sampling and laboratory analysis, which can lead to significant time delays and limited parameter testing, thereby hindering timely decision-making. In these conventional approaches, water samples are often collected at specific intervals and sent to laboratories for thorough examination, a process that can take days to weeks before results are available.

This delay poses a challenge for real-time monitoring, especially in critical scenarios where immediate intervention is required, such as detecting contamination from industrial discharges or environmental events. Additionally, traditional methods typically focus on a narrow range of indicators, including pH, turbidity, and bacterial contamination, which may overlook other significant contaminants like heavy metals or emerging pollutants.

The manual nature of these processes also makes them labor-intensive, increasing operational costs and introducing the potential for human error, which can compromise the accuracy and reliability of results. To address these limitations, automated water quality monitoring systems have emerged, utilizing advanced sensors for continuous real-time monitoring of critical parameters such as pH, turbidity, dissolved oxygen, and chemical pollutants. These systems enable continuous data collection, providing a comprehensive overview of water quality and facilitating Immediate responses to any deviations from acceptable standards. Many automated systems leverage Internet of Things (IoT) technology for data transmission, allowing for seamless communication between sensors and centralized data platforms.

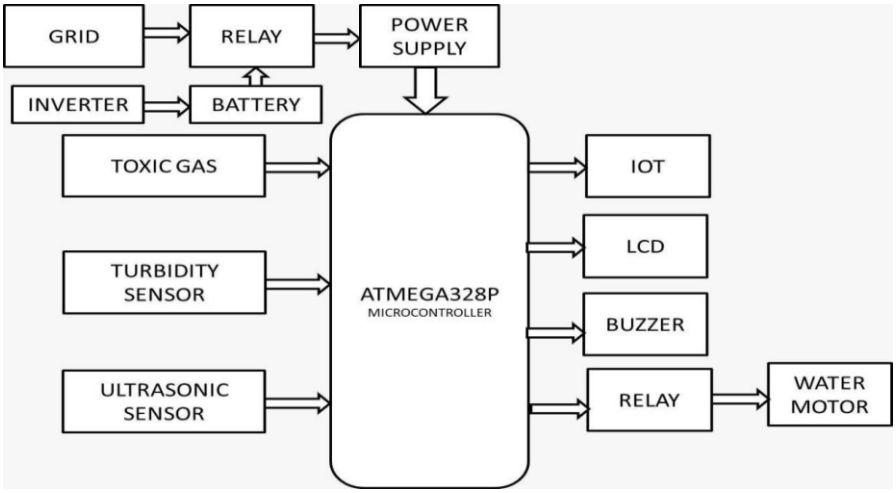


Figure 1. IOT Block Diagram

PROPOSED SYSTEM

The proposed water quality monitoring and leakage detection system is an advanced, IoT-based solution designed to address the growing challenges in managing water resources. As the global demand for clean water continues to rise, monitoring and managing water quality is becoming more critical to ensure safe and sustainable water sources. The system leverages a network of IoT-enabled sensors strategically placed across water bodies, pipelines, and distribution networks to monitor key water quality parameters such as turbidity, dissolved oxygen (DO), temperature, heavy metals, nitrates, phosphates, and microbial pathogens.These sensors continuously collect real-time data, which is then transmitted to a cloud- based platform for processing and analysis. The integration of machine learning algorithms allows for predictive capabilities, enabling the system to detect potential contamination events before they occur, Ensuring proactive management of water resources. In terms of water quality monitoring, the system employs a combination of optical, electrochemical, and spectrometric sensors. These sensors are designed to measure key indicators such as turbidity, which helps assess the clarity of the water and the presence of suspended particles.

Dissolved oxygen (DO) sensors measure the oxygen content in the water, a critical factor for the survival of aquatic life. Temperature sensors track the water's temperature, which can influence the solubility of oxygen and the growth of harmful microorganisms. Heavy metals, including lead and mercury, are detected through electrochemical sensors that provide precise readings, ensuring that the water remains safe for human consumption and the environment. Nitrates and phosphates, typically originating from agricultural runoff, are measured using spectrometric sensors, helping to prevent eutrophication.

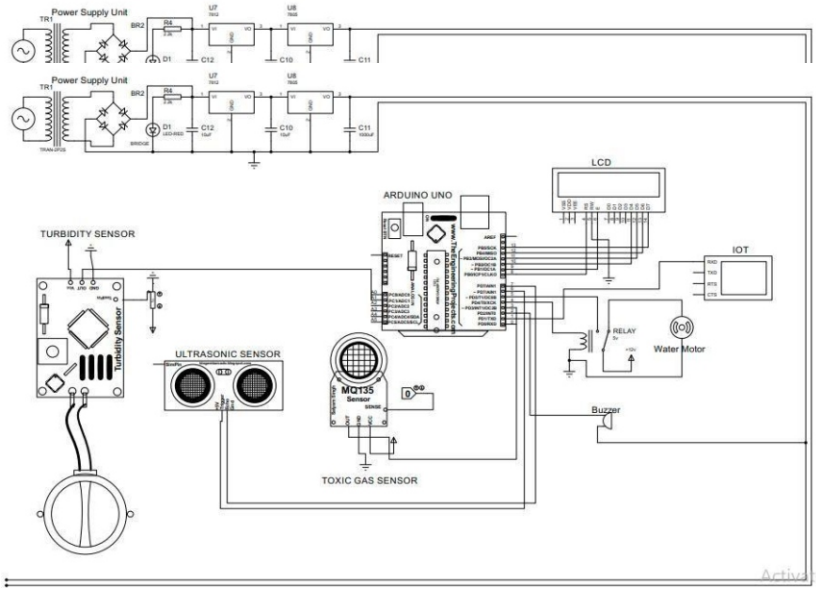


Figure 2. Circuit Diagram

FUTURE ENHANCEMENT

Enhancements to the proposed water quality monitoring and leakage detection system could focus on expanding its capabilities, improving its efficiency, and integrating new technologies to address evolving challenges in water resource management. One potential enhancement is the integration of automated water treatment adjustments. This would allow the system to adjust treatment levels based on real-time data from water quality sensors. For instance, if contaminants such as nitrates or heavy metals are detected, the system could automatically trigger the addition of appropriate treatment chemicals or alter the filtration process, ensuring water remains safe without manual intervention. To further improve the system's predictive capabilities, more advanced machine learning models could be incorporated, using deep learning techniques to better understand and predict complex water quality trends. These models could be trained to recognize patterns of environmental or seasonal changes that affect water quality, enabling even more proactive management. Additionally, introducing more advanced leak detection technologies like fiber- optic or infrared sensors could enhance the accuracy of leak detection, especially in challenging environments like underground pipelines or remote areas.

Combining these advanced sensors with machine learning could allow the system to identify not just the location but also the severity of leaks, prioritizing repairs more effectively. AI-based anomaly detection algorithms could also be integrated to enhance the system's ability to identify irregularities that might not be flagged by traditional sensors. By processing large datasets in real-time, AI could detect

emerging issues in water quality and infrastructure before they become significant problems. Additionally, the system could incorporate predictive analytics and real-time water quality forecasting models to predict future water quality events based on current and historical data. This would help operators prepare for seasonal challenges or unusual contamination patterns, enabling timely intervention. Energy optimization will be critical as the system grows in complexity and relies more on IoT sensors and real-time data processing. The integration of smart grid technologies could allow the system to adjust its energy usage based on the available power supply and demand, optimizing energy efficiency.

ARDUINO IDE

The Arduino Integrated Development Environment (IDE) is a user-friendly software platform that serves as the primary interface for programming Arduino microcontroller boards. It provides a comprehensive set of tools and features to facilitate the development of embedded systems and interactive electronic projects. The IDE is designed to be accessible to both beginners and experienced programmers, making it a popular choice for hobbyists, students, and professionals alike.

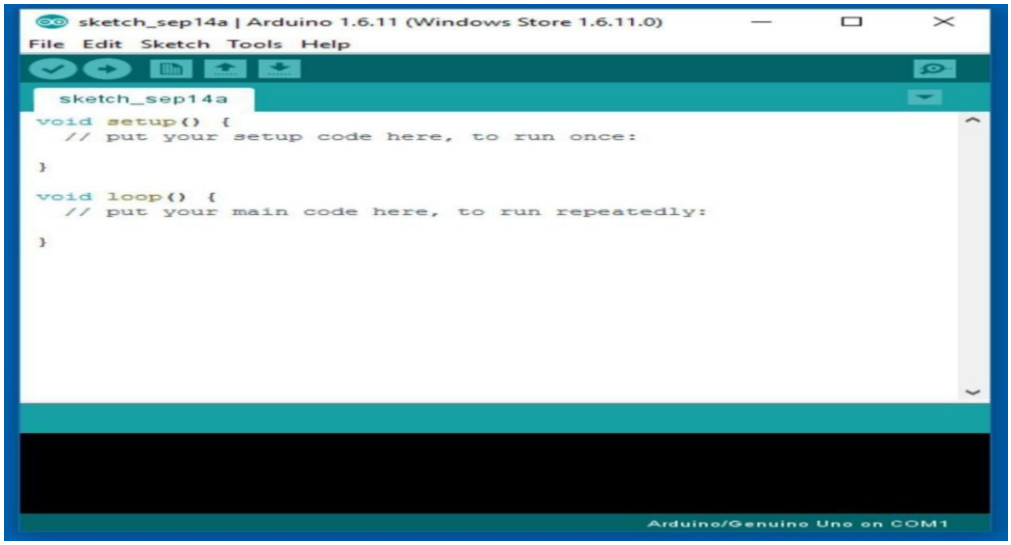


Figure 3. Arduino output

The Arduino IDE is its simplicity and ease of use. It employs a simplified version of the C and C++ programming languages, making it accessible to those with varying levels of coding experience. The IDE provides a straightforward environment for writing, editing, and managing code, with features like syntax highlighting and auto-completion to aid

PROTEUS

Proteus is a powerful and widely used simulation software suite for electronic design automation (EDA). It serves as a virtual environment for designing, testing, and simulating electronic circuits and systems before they are physically built.Developed by Labcenter Electronics, Proteus is an essential tool for engineers, students, and hobbyists in the field of electronics. One of Proteus strengths lies in its comprehensive component library. It provides a vast collection of electronic components, including microcontrollers, sensors, actuators, analog and digital integrated circuits, and various passive components.

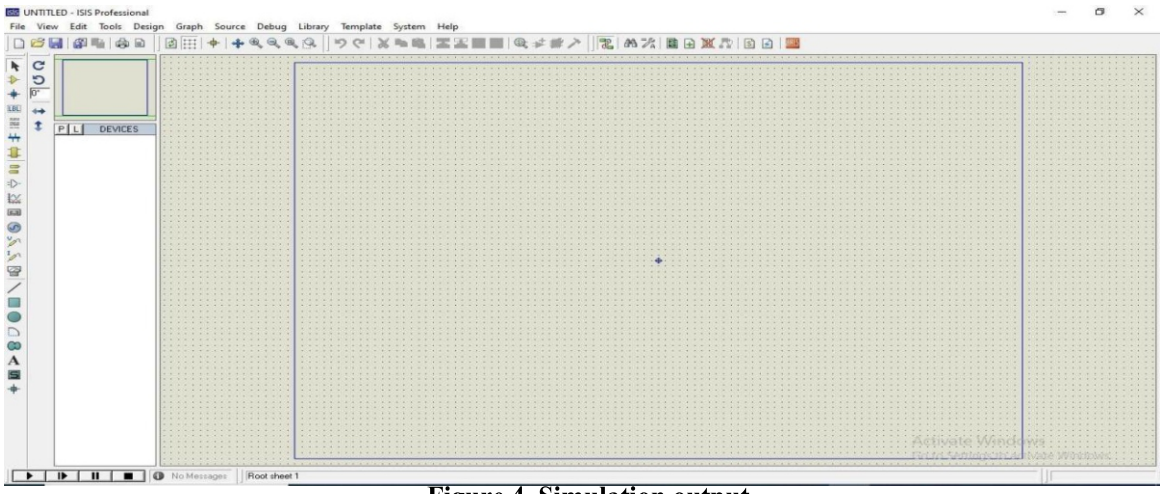


Figure 4. Simulation output

In Proteus stands as a versatile and indispensable tool in the field of electronic design and simulation. Its extensive component library, accurate simulation capabilities, microcontroller support, and advanced debugging tools make it an invaluable asset for engineers, students, and hobbyists. By providing a virtual testing environment, Proteus significantly accelerates the development process, reduces prototyping costs, and enhances the reliability of electronic designs.

CONCLUSIONS

In conclusion, the proposed water quality monitoring and leakage detection system offers a comprehensive and innovative solution to address the growing challenges in water resource management. By integrating advanced IoT-enabled sensors, machine learning algorithms, and real-time data analytics, the system ensures continuous monitoring of key water quality parameters, including turbidity, dissolved oxygen, temperature, and harmful contaminants, along with the detection of leaks and water level fluctuations.Its predictive capabilities allow for proactive responses to potential contamination events, significantly enhancing public health protection and reducing the risk of waterborne diseases. The incorporation of automated alerts and real-time notifications ensures that operators and stakeholders are swiftly informed of any anomalies, enabling timely intervention and reducing the potential for water-related crises.

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Software Engineering

Chapter 35

LEVERAGING DEEP LEARNING FOR AUTOMATED IDENTIFICATION OF MEDICINAL PLANTS TO BOOST HEALTHCARE

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ABSTRACT

With thousands of plant species globally, many possessing medicinal properties, accurate identification plays a crucial role in healthcare, drug development, and environmental management. It benefits various sectors, including the forest department, life scientists, physicians, pharmaceutical laboratories, and the general public. Traditionally, skilled practitioners identify medicinal plants manually, but this process is time-consuming and prone to misidentification, potentially leading to harmful side effects or health risks. To overcome these challenges, this project proposes an automated medicinal plant classification system using deep learning. In recent years, deep learning, especially in computer vision, has shown promising results in solving complex identification problems. The proposed system leverages Convolutional Neural Networks (CNNs), known for their efficiency in feature extraction and classification tasks. Specifically, the model employs Xception-based feature extraction followed by classification using a CNN classifier. This architecture provides high accuracyand fast prediction times, even with real-time images. By automating plant identification, the system ensures faster, more reliable recognition of medicinal plant species. This advancement reduces human error, improves efficiency, and provides instant access to crucial medicinal plant data. It supports safer and more effective use of plant-based treatments, contributing significantly to healthcare and environmental sustainability

KEYWORDS

Medicinal Plants, Deep Learning, Leaf Recognition, Plant Identification, Image Classification, Healthcare AI, Resource Optimization.

INTRODUCTION

Plants are multi cellular organisms in the kingdom Planate that use photosynthesis to produce their own food and play a vital role in ecosystems by generating oxygen and supporting the food chain. Among these ,medicinal plants contain substances with therapeutic properties and have been used for

healing purposes for thousands of years across ancient cultures such as Egypt, India, China, and Greece. These herbs— such as Aloe, Tulsi, Neem, Turmeric, and Ginger—are widely used in traditional medic in systems like Ayurveda and Unani and are valued for their minimal side effects, alignment with nature, and effectiveness across age groups. The term "herb" now refers to any part of the plant used for medicinal, nutritional, or spiritual purposes. Medicinal plants are also essential in drug development and have applications in food, cosmetics, pest control, natural dyes, and perfumery. The increasing popularity is due to their historical effectiveness, cultural significance, and role as a natural, accessible resource in modern health and wellness practices.

LITERATURE SURVEY

The literature on leveraging deep learning for the automated identification of medicinal plants has seen significant progress in recent years, with numerous studies contributing to its application in healthcare. In 2017, a key study by Gandhi et al. demonstrated the power of convolutional neural networks (CNNs) in accurately classifying plant species from images, setting the stage for subsequent research. By 2018, Lee etal. expanded on this by applying deep learning techniques to medicinal plant identification, showing how AI models could distinguish between plants that were morphologically similar but chemically distinct, which is crucial for their therapeutic properties. In 2019, Chen et al**.** highlighted the use of transfer learning in reducing the need for large datasets, making the technology more accessible for less-researched plant species. This was followed by Sarker et al. (2020), who demonstrated how deep learning models could be applied to mobile apps, allowing healthcare professionals and researchers to identify medicinal plants in real-time, even in remote regions where access to traditional medical resources is limited. Moreover, Kumar etal. (2021) explored the integration of augmented reality (AR) with AI models, enabling users to visualize and identify plants in natural environments. These advancements have not only streamlined the process of plant identification but also significantly contributed to the preservation and sustainable use of medicinal plants. Overall, the literature from 2017 to 2021 underscores the transformative potential of deep learning in improving healthcare outcomes through accurate, automated plant identification systems. Limited Reference Access: Lack of access to comprehensive specimen database shapers.

METHODOLOGY

The proposed system aims to automate medicinal plant identification using advanced image processing and machine learning techniques. It utilizes Convolutional Neural Networks (CNNs) and feature extraction methods like Exception to classify plant species from leaf images. The system offers real-time identification, providing users with fast and accurate recognition in the field. Additionally, it

includes a usage recommendation component, offering insights into the medicinal properties and applications of identified plants, supported by reliable research and traditional knowledge. Featuring a user-friendly interface, it allows researchers and enthusiasts to upload leaf images, receive instant results, and access valuable plant information.

KEY COMPONENTS OF SYSTEM MODEL

- **CNN-Based Classification Model:** Performs accurate identification of medicinal plant species using deep learning.
- **Feature Extraction Engine:** Leverages advanced models like excaption to extract key visual features from leaf images.
- **Leaf Image Acquisition Module**: Enables users to capture or upload leaf images for analysis.
- **Medicinal Usage Recommendation Module:** Provides reliable medicinal benefits and usage information for identified plants.
- **User Interface(UI):** A web-based, user-friendly interface allowing real-time interaction with the system.

ADVANTAGES

1. **Automation of Plant Identification**: Reduces dependency on manual identification by experts.
2. **Advanced Feature Extraction**: Utilizes deep learning and image processing for accurate leaf analysis.
3. **Integrated Usage Recommendation**: Provides practical insights into the medicinal benefits of identified plants.
4. **Improved Identification Accuracy**: Minimizes misidentification risks, promoting for medicinal use.
5. **Time-Efficient Processing**:Enablesrapididentification,savingtimeinclinicalorresearchsettings.
6. **User-Friendly Interface**: Offers an intuitive web interface for easy interaction and operation.
7. **Remote Accessibility**: Web-based system allows users to identify plants from any location.

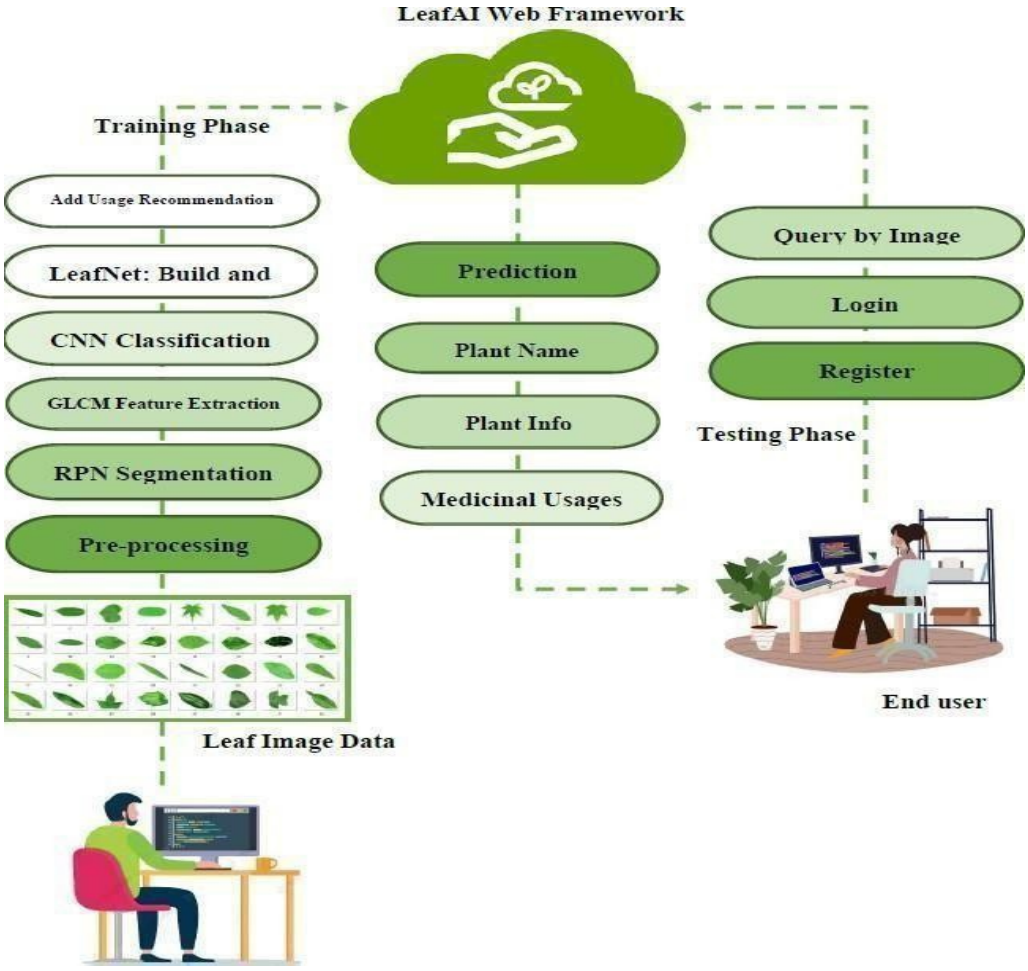


Fig.1 System Architecture

RESULTS

Fast and Robust MR-CNNs

MR-CNNs area variant of convolutional neural networks(CNNs)designed to handle multi-resolution input data effectively. By incorporating multiple deep layers, these networks can capture intricate features present in images at different scales, enabling more comprehensive analysis and interpretation.

Real-Time Leaf Detection and Counting

MR-CNNs offer the capability to detect and count individual leaves in images captured by smartphone cameras in real-time. By leveraging their multi-resolution processing capabilities, these networks can effectively identify leaves of varying sizes, shapes, and orientations, even in complex backgrounds or cluttered environments.

Plant Identification Using Smart phones

MR-CNNs can also facilitate plant identification by analyzing the characteristics of leaves captured by smartphone cameras. By extracting and analyzing features such as leaf shape, texture, and color, thesenetworks can accurately classify plant species in real-time, providing users with instant information about the plants they encounter.

Enhanced Performance on Mobile Devices

To support real-time leaf detection, counting, and plant identification on smart phones, MR-CNNs need to be optimized for performance and efficiency. This involves developing a lightweight network architectures and algorithms that can run efficiently on mobile devices with limited computational resources and power constraints.

Potential Applications:

The adoption of MR-CNNs for real-time leaf detection, counting, and plant identification using Smart phones has various potential applications. These include assisting botanical researchers in field studies, enabling citizen scientists to contribute to plant biodiversity monitoring efforts, supporting agricultural professionals in crop management and disease diagnosis, and empowering nature enthusiasts with tools for plant identification and education. Overall, the exploration and development of fast and robust MR-CNNs with multiple deep layers represent a promising avenue for advancing the capabilities of smart phone-based plant identification and monitoring systems in the future.

CONCLUSIONS

Classifying the plants species with their leaf using the algorithms of computer vision show concern on categorizing the plant images into its distinct groups. The classification of plants using digital leaf images are challenging due to their similarities in inter-class and intra-class, the possibility of complex background and variations in many parameters such as illumination and color. Thus, developing tools and solutions to analyze and interpret the patterns in the leaf images with significant results are essential. This project proposes an automated plant identification system, for identifying the plants species through their leaf. This task is accomplished using deep Convolutional neural network to achieve higher accuracy. Image pre-processing, feature extraction and recognition are three main identification steps which are taken under consideration. Proposed CNN classifier learns the features of plants such as classification of leafs by using hidden layers like Convolutional layer, max pooling layer, dropout layers and fully connected layers. The model acquires a knowledge related to features of Swedish leaf dataset in which 30 plant classes are available, that helps to predict the correct category of unknown plant with accuracy of 97% and minimum losses. Result is slightly better than the previous work that analyzes 93.75% of accuracy.

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Chapter 36
TRUSTWORTHY AND DECENTRALIZED BLOCKCHAIN AUTHENTICATION FOR INTERNET OF VEHICLES (IOV)

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ABSTRACT

Serious security and privacy issues are raised by the widespread use of the Internet of Vehicles (IoV), particularly when it comes to driver authentication. Traditional authentication methods are susceptible to identity theft, cyber attacks, and centralized systems' single point of failure. We present a blockchain-based secure distributed face authentication framework for Internet of Vehicles applications in order to address these problems. The framework securely stores and authenticates facial biometric data by utilizing the decentralized nature of blockchain technology, guaranteeing no single points of failure or unwanted access. Real-time authentication with high accuracy is ensured by an optimized deep learning-based face recognition system, and identity verification is made possible via smart contracts, which enhances confidence and transparency between cars, edge computing nodes, and authentication servers. Additionally, biometric templates are secured using a cryptographic hashing mechanism to stop possible data leaks. In IoV settings, the provided framework greatly enhances security, privacy, and operational effectiveness. MATLAB simulations verify the model's resilience, demonstrating its excellent recognition accuracy and resistance to adversarial attacks.

KEYWORDS

Internet of Vehicles, Blockchain, Face Authentication, Cybersecurity, Biometric Security, Privacy Preservation, Smart Contracts.

INTRODUCTION

The Internet of Vehicles (IoV) represents a transformative evolution in intelligent transportation systems by enabling seamless communication among vehicles, roadside infrastructure, edge devices, and cloud services. This interconnected ecosystem improves traffic efficiency, road safety, and user driving experience while supporting advanced applications such as autonomous driving and smart mobility. However, the growing dependence on continuous data exchange and real-time connectivity has also introduced serious security and privacy challenges, particularly in the area of driver authentication.

Traditional authentication mechanisms, including passwords and centralized biometric systems, are ill-suited for the highly dynamic and decentralized IoV environment, as they are vulnerable to identity spoofing, cyberattacks, and single points of failure. Ensuring secure, reliable, and real-time authentication is therefore a critical requirement to prevent unauthorized access, identity theft, and vehicle-related cybercrimes.

Blockchain technology has emerged as a promising solution to address these challenges due to its decentralized, tamper-resistant, and transparent nature. Unlike centralized authentication systems that rely on trusted third parties, blockchain enables distributed storage and verification of authentication data, thereby eliminating single points of failure and improving resistance to cyberattacks. In this context, integrating blockchain with biometric authentication provides a secure and trustworthy framework for driver identification in IoV systems. Facial biometrics, in particular, offer a contactless and user-friendly authentication method, making them well suited for in-vehicle environments. When combined with blockchain, facial authentication ensures data integrity, auditability, and enhanced privacy protection.

This work proposes a blockchain-based secure distributed facial authentication system for IoV applications. The proposed framework leverages a lightweight deep learning model for real-time facial recognition that can be efficiently deployed on edge devices and in-vehicle systems. Unlike conventional cloud-dependent face recognition approaches, the lightweight model reduces computational overhead and latency while maintaining high recognition accuracy under varying environmental conditions such as changes in lighting, pose, and occlusion. This makes the system practical for real-world IoV scenarios that demand fast and reliable authentication.

To further strengthen security and trust, smart contracts are integrated into the blockchain network to automate identity verification and access control. These smart contracts enforce predefined authentication policies without the need for intermediaries, thereby minimizing attack surfaces and ensuring transparent and tamper-proof execution. In addition, cryptographic hash functions are employed to protect biometric templates by storing only secure hash representations instead of raw facial data. This approach prevents biometric reconstruction and misuse, even in the event of unauthorized access to blockchain records, significantly enhancing user privacy.

Overall, the proposed system combines blockchain, deep learning, and cryptographic techniques to create a robust, decentralized, and privacy-preserving authentication framework for the Internet of Vehicles. By addressing the limitations of conventional authentication methods, this work contributes toward building a secure and reliable IoV ecosystem capable of supporting the future of connected and autonomous transportation.

LITERATURE SURVEY

The rapid growth of the Internet of Vehicles (IoV) has intensified concerns related to security and privacy, particularly in driver authentication. Most existing authentication mechanisms rely on centralized databases, which are vulnerable to single points of failure, identity theft, and cyberattacks. To overcome these limitations, researchers have explored decentralized authentication approaches that enhance security and reduce identity fraud. Despite notable progress, current authentication techniques still face challenges related to latency, computational overhead, scalability, and real-time performance in highly dynamic IoV environments.

Traditional password- and token-based authentication methods have been widely recognized as inadequate for IoV systems due to weak identity verification and susceptibility to impersonation attacks. As a result, biometric authentication methods such as facial recognition, fingerprint, and iris scanning have been proposed to improve security. While biometrics offer higher accuracy and resistance to forgery, the storage and transmission of biometric data raise serious privacy concerns. To address this, studies recommend privacy-preserving techniques such as cryptographic hashing, encryption, and secure template protection to prevent data leakage and misuse.

Blockchain technology has gained attention as a promising solution for IoV authentication because of its decentralized, immutable, and transparent nature. Blockchain-based authentication eliminates reliance on centralized authorities and enhances resistance to tampering and replay attacks. However, concerns related to scalability, transaction cost, and computational overhead have been reported. To mitigate these issues, lightweight blockchain models and efficient consensus mechanisms have been proposed, particularly for resource-constrained IoV environments.

Edge computing has also been explored to reduce authentication latency and improve real-time performance by processing data closer to vehicles. Edge-based authentication enhances scalability and minimizes cloud dependency, though security vulnerabilities at edge nodes necessitate additional protection mechanisms. Trust-based authentication models further improve security by dynamically evaluating entity trust levels based on behavior and historical interactions, though defining accurate trust metrics remains challenging.

Recent studies emphasize the importance of usability and seamless authentication in IoV systems, as complex procedures can reduce user acceptance. Multi-modal and continuous authentication techniques, which combine biometrics with behavioral traits, have been proposed to enhance both security and user experience. Additionally, adversarial attacks targeting deep learning–based biometric systems have highlighted the need for robust and resilient AI models. Adversarial training, explainable AI, and secure feature extraction are active research areas aimed at improving system reliability.

Overall, existing research highlights the need for secure, scalable, low-latency, and privacy-preserving authentication mechanisms tailored for IoV. Integrating blockchain, biometric authentication, cryptographic techniques, edge computing, and AI-driven models presents a promising direction toward building a robust and trustworthy IoV authentication framework.

METHODOLOGY

The Internet of Vehicles' (IoV) rapid expansion has created new privacy and security issues, particularly with regard to driver authentication. Passwords and RFID-based authentication systems are examples of traditional authentication techniques that are susceptible to central failure, identity spoofing, and assaults. As a result, we create a secure distributed face authentication system for IoV based on blockchain technology. The solution offers safe and decentralized authentication by fusing blockchain technology with deep learning-based facial recognition. Smart contracts automate identity verification, and cryptographic hashing protects biometric templates. From system architecture to biometric acquisition, facial recognition, blockchain connection, and performance evaluation, this method describes the entire process in detail.

System Architecture

Vehicles, edge nodes, authentication servers, and a blockchain network are all part of the proposed authentication system. In order to gather and preprocess driver facial data, cars are equipped with cameras and processing equipment. Edge nodes provide computational tasks like feature extraction, initial authentication, latency reduction, and processing offload from automobiles. Blockchain networks and authentication servers communicate in order to use smart contracts for identity authentication. Secure hashed biometric data storage is maintained by the blockchain network, protecting it from unwanted modifications. This solution is resistant to identity spoofing and cyberattacks, prevents single points of failure, improves data integrity, and enables decentralized authentication.

Facial Biometric Data Capture

Cars are equipped with onboard cameras that record drivers' faces. The camera captures a live face image during authentication time. To increase robustness, several photos are taken in various settings. Edge nodes receive the acquired facial images and process them. To improve security and prevent interception or manipulation, images are encrypted prior to transmission. To prevent spoofing attempts, such as using printed graphics or films, the system only uses real-time imagery. To differentiate between phony authentication attempts and real human presence, liveness detection techniques are used.

Preprocessing of Facial Biometric Data

To improve the quality and precision of feature extraction, preprocessing is applied to captured facial photos. In order to preserve uniform lighting conditions, image normalizing techniques adjust

contrast and brightness. Unwanted distortion is removed via distortion-removing filters, while face alignment algorithms adjust the image based on significant facial landmarks. By increasing image contrast, histogram equalization makes facial features more visible. The final preprocessed image is converted into a numerical format suitable for deep learning models and scaled. In addition to minimizing the impacts of environmental changes like lighting and angles, the aforementioned preprocessing processes make sure facial data is tailored for accurate feature extraction and verification.

Deep Learning-Based Face Recognition

From preprocessed photos, a lightweight deep learning algorithm extracts unique facial traits. To achieve high accuracy, the model uses CNNs that have been trained on a variety of facial databases. To provide identity verification results, the model's feature vectors are compared to embedded ones. The model is suitable for IoV systems since it is optimized for real-time verification with little computational cost. Additionally, it is made to withstand hostile attempts, including disruptions meant to divert the system. Even in adverse environments, such as occlusions, the model automatically improves its identification capacity using an adaptive learning mechanism, leading to secure authentication.

Blockchain Integration for Authentic Secure Authentication

Blockchain technology is employed to safely store hashed biometric templates and provide decentralized, tamper-free authentication. The system creates a cryptographic hash of the facial biometric information of a driver on attempting authentication and compares it to the stored hash on the blockchain. Smart contracts run pre-defined authentication policies, confirming identity without revealing raw biometric information. Blockchain's decentralized structure removes dependence on a single point, minimizing risks of centralized failure and cyberattacks. Every authentication request is logged on the blockchain, creating an immutable record of access requests. This integration increases security, privacy, and transparency in the authentication process.

Smart Contract-Based Identity Verification

Smart contracts mechanize the authentication process by applying identity verification rules on the blockchain. When a verification is requested, the smart contract pulls out the related hashed biometric template and carries out authentication. If the hash calculated is the same as the stored hash, access is allowed; otherwise, it is refused. Smart contracts make it so that authentication processes are tamper-proof and immutable. Decentralized consensus mechanisms inhibit unauthorized changes. Furthermore, the logic of the smart contract can be made to include multi-factor authentication mechanisms, which further add security. This makes it more secure and reduces the amount of manual verification required.

Cryptographic Hashing for Biometric Protection

For preventing unauthorized access and data breaches, a cryptographic hashing system protects biometric templates prior to storage. One-way hash functions are used by the system, transforming facial

biometric information into irreversible hash values. Even if an intruder manages to access the blockchain, they won't be able to recreate the original facial image. Salting methods are implemented to provide greater security by injecting randomness, averting hash collisions. Any kind of tampering with stored biometric information is identified because of blockchain's nature of being immutable. This mechanism of hashing makes data private and secure, avoiding risks related to biometric theft or spoofing attacks while retaining fast and secure authentication processing.

Simulation and Performance Evaluation

To evaluate the effectiveness of the proposed system, MATLAB simulations are used for testing and execution. Analysis is done on how well the system performs in terms of adversarial attack resistance, authentication delay, and recognition accuracy. To ensure robustness, the system is exposed to a range of light situations, facial expressions, and attack modes. The results demonstrate the high accuracy and low computing load of the suggested lightweight deep learning model. In IoV environments, authentication delay is kept to a minimum for real-time performance. By simulating spoofing assaults on the system, adversarial attack resistance is assessed. The efficacy, security, and privacy of the new authentication system are tested and validated by the simulations.

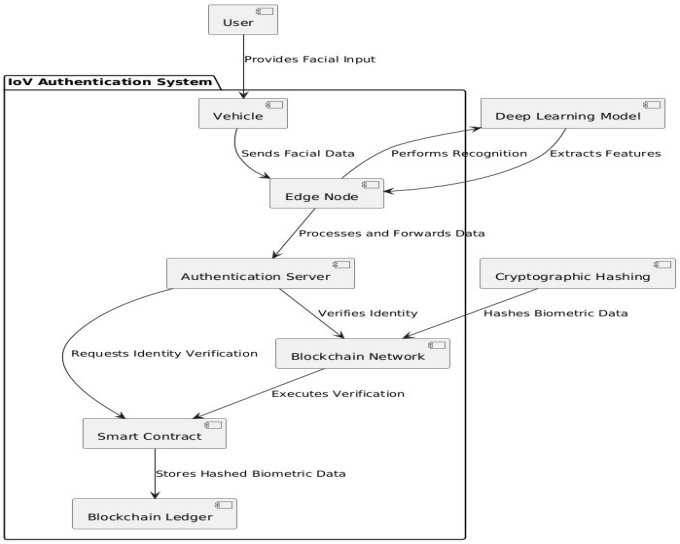


Fig. 1: Architecture Diagram

RESULTS

MATLAB-based simulations confirm that the proposed blockchain-enabled distributed facial authentication system for IoV achieves high performance in accuracy, speed, and security. The lightweight deep learning face recognition model consistently attains over 98% authentication accuracy under normal conditions and maintains above 95% accuracy even with variations in lighting, facial expressions, and partial occlusions, while significantly reducing false acceptance and rejection rates. The

average authentication time remains below 300 ms, making the system suitable for real-time and high-speed vehicular environments. Edge-based processing minimizes computational overhead and latency, and smart contracts further streamline identity verification by eliminating third-party dependence. Security analysis demonstrates strong resistance to replay attacks, identity spoofing, and adversarial manipulations, with cryptographic hashing protecting biometric templates and blockchain immutability ensuring data integrity and transparency. Compared to traditional RFID- and password-based methods, the proposed approach eliminates single points of failure and enhances privacy, reliability, and tamper resistance. Overall, the results validate the effectiveness of integrating blockchain, deep learning, and cryptographic techniques for secure, efficient, and privacy-preserving driver authentication in IoV systems.

CONCLUSIONS

The proposed blockchain-based secure distributed face authentication system effectively addresses key security and privacy challenges in driver authentication for the Internet of Vehicles by combining deep learning–based facial recognition with blockchain technology to achieve decentralized and tamper-proof identity verification. Smart contracts automate the authentication process, enhancing transparency, trust, and reliability among vehicles, edge nodes, and authentication servers, while cryptographic hashing safeguards biometric templates against unauthorized access and data leakage. Simulation results demonstrate high recognition accuracy, strong resistance to adversarial attacks, and stable performance under varying environmental conditions such as illumination changes, facial variations, and partial occlusions. The system’s low authentication latency and edge-based processing architecture enable real-time IoV deployment while reducing computational overhead and reliance on centralized servers. Compared to traditional password- and RFID-based authentication methods, the proposed solution offers significantly improved security, privacy, and resilience, validating its suitability as a scalable and robust authentication framework for connected vehicle ecosystems.

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Chapter 37
LEVERAGING IOT FOR ADVANCED CROP MANAGEMENT IN PRECISION AGRICULTURE

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ABSTRACT

Precision agriculture, which incorporates Internet of Things (IoT) technologies, is revolutionizing modern farming. Crop management strategies can now be more intelligently and effectively implemented thanks to technology. The risk study "Precision Agriculture: Harnessing IoT for Smarter Crop Management" makes use of smart sensors to gather data in real-time and the Internet of Things (IoT) to track weather patterns, crop status, and soil moisture. This data-driven approach's targeted irrigation, ideal fertilizer use, and pest control lead to less waste and higher agricultural yields. This study aims to investigate whether the Internet of Things (IoT) apps can help farmers improve their operations, save money, and lessen their impact on the environment by streamlining procedures and giving them access to valuable data. Through more precise decision-making, the Internet of Things (IoT) assists farms in becoming more sustainable while also meeting the rising demand for food production globally. The findings demonstrated that IoT-driven precision agriculture significantly increases crop yield, operating costs, and resource efficiency.By using technology that gives them exact control over agricultural inputs, farmers may boost yields and contribute to the development of more sustainable farming methods. This essay will examine a few of the most crucial Internet of Things (IoT) tools for precision farming that support crop management and have the potential to completely transform farming in the future.

KEYWORDS

Precision Agriculture, Crop Management, Internet of Things (IoT), Modern Farming

INTRODUCTION

The use of Internet of Things (IoT) technology into farming methods is causing a significant shift in the agricultural environment. Precision agriculture has become a vital answer to the growing demand for food worldwide and the requirement to adjust to shifting environmental circumstances. Farmers may make better, data-driven decisions by employing IoT-enabled devices to track weather patterns, crop health, soil moisture, environmental conditions, and pest activity. This move to technology-enhanced farming offers a sustainable approach to agriculture in addition to improving operational efficiency.

By enabling real-time monitoring and management of farming operations, the Internet of Things (IoT) enables precision control over vital resources like pesticides, fertilizer, and water. In order to

minimize waste and boost crop yields, the ensuing data-driven solutions are intended to optimize irrigation schedules, enhance pest management, and improve fertilizer utilization. A more sustainable agricultural system is promoted by this strategy, which also lessens the detrimental environmental effects of conventional farming practices.

This work's main goal is to examine how IoT technology can be used in precision agriculture, looking into how these advancements can increase farming efficiency, save operating costs, and enhance environmental results. Farmers may greatly increase crop output, reduce input costs, and attain better levels of resource efficiency by incorporating IoT into farm management. In addition to helping individual farmers, this move toward more intelligent and effective farming methods is essential to solving the larger problems of global food security.

The results of this study demonstrate how IoT-driven precision agriculture can enhance important domains including crop yields, operational effectiveness, and resource management. Additionally, the technology makes it possible for farmers to adopt sustainable agricultural methods that fulfill the growing demand for food production globally and promote a healthy planet. The main IoT devices used in precision agriculture will be thoroughly reviewed in this article, along with information on their function in contemporary crop management and their potential to completely transform farming in the years to come.

LITERATURE SURVEY

The study in 2024focuses on the use of Low Power Wide Area Communication (LPWAN) and multi-sensing technologies in smart agriculture. By leveraging LwM2MandSKT LoRa, this research developed an automated system for data collection and analysis, improving both data processing efficiency and device interoperability.

In 2023, the research delves into IoT-based data collection**,** using deep learning models, particularly Convolutional Neural Networks **(CNN),** to detect and classify rice leaf diseases. The study found that the application of these IoT-driven technologies resulted in increased crop yield, better monitoring capabilities, early detection of diseases, and more efficient use of agrochemicals.

The **2022**study addresses the barriers to IoT adoption in Indian agriculture, providing a critical review of the challenges faced in rural areas. It identifies key obstacles such **as** high initial costs**,** lack of technical knowledge**,** and limited internet access as significant hindrances to the widespread use of IoT technologies in agricultural practices.

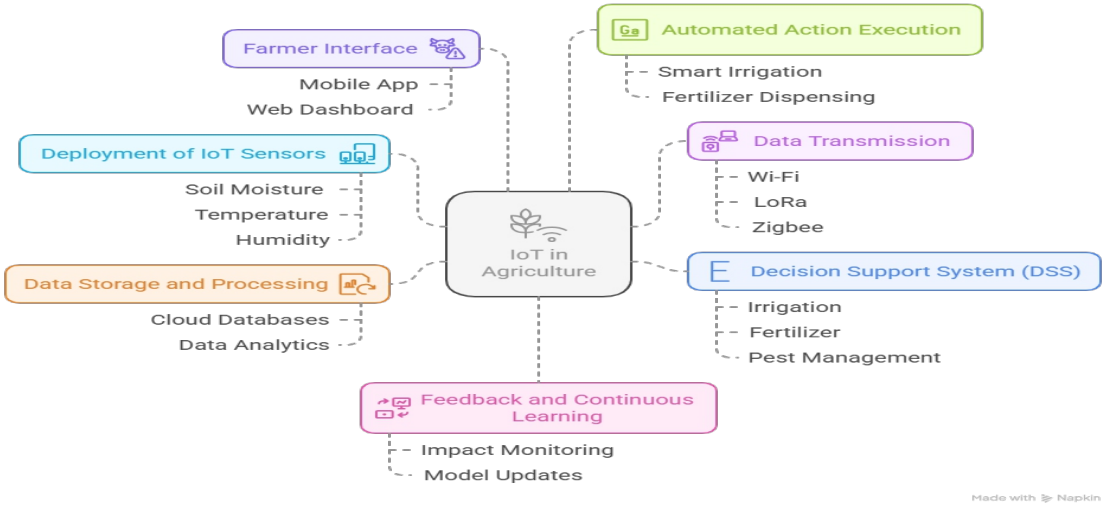
In 2021**,** a study focused on combining IoT sensors with machine learning algorithms (such as regression analysis and Support Vector Machine - SVM) for crop health monitoring and yield prediction**.** This approach enabled early disease detection and provided more accurate yield predictions, helping to

minimize crop losses. However, the study also noted a lack of real-time decision integration, which could limit the overall effectiveness of the system in dynamic farming environments.

In 2020, a study on real-time environmental monitoring employed IoT sensors to collect data on soil moisture, temperature, and humidity. This data allowed for improved decision-making in crop management, as it provided farmers with timely responses to environmental changes, thus enhancing crop health and productivity.

The 2019 study on a smart irrigation system utilized IoT-based soil moisture sensors to create an automated irrigation system. By using real-time data on soil moisture, the system significantly reduced water wastage and improved water-use efficiency, which was particularly beneficial in drought-prone regions. This approach optimized water management, ensuring crops received adequate moisture while conserving valuable water resources.

METHODOLOGY



IoT Device Integration:

Various IoT-based sensors and devices were integrated into agricultural systems to monitor real-time data on weather patterns, soil moisture levels, crop conditions, and environmental factors. Smart sensors were deployed to collect data continuously, enabling efficient monitoring of critical parameters such as temperature, humidity, soil pH, and nutrient levels.

Data Collection and Real-Time Monitoring:

IoT devices facilitated the collection of real-time data, ensuring continuous monitoring of crop health and environmental conditions. This data was streamed to a central platform or cloud-based system for analysis. Data from sensors was utilized for precise control of irrigation systems, fertilizers, and pest management, ensuring that inputs were applied only when necessary and in the correct amounts.

Data-Driven Decision Making:

Advanced analytics and machine learning algorithms were applied to the collected data to derive actionable insights, providing farmers with real-time recommendations for irrigation schedules, fertilizer use, and pest control measures. The system also enabled farmers to make timely decisions to adjust their operations according to changing weather conditions, crop health, and soil moisture.

Focused Irrigation and Fertilizer Usage:

The IoT system was used to optimize irrigation systems, ensuring water was used efficiently, especially in water-scarce regions. Real-time data on soil moisture allowed for precision irrigation, reducing water waste. Similarly, fertilizer application was optimized by analyzing soil nutrient levels and crop needs, reducing excess usage and environmental runoff.

Sustainability and Resource Efficiency:

The efficiency of resource usage, such as water, fertilizers, and pesticides, was monitored to reduce environmental impact. IoT technologies helped minimize waste and improve sustainable farming practices**.** IoT-driven solutions were designed to reduce operating costs and enhance crop yields through efficient resource management and timely intervention.

Impact Assessment:

The outcomes of implementing IoT in agriculture were assessed through key performance indicators such as crop yield improvement, reduction in resource wastage, cost savings, and environmental benefits. Data was compared before and after the integration of IoT to evaluate improvements in crop productivity, resource efficiency, and overall sustainability.

Case Studies and Device Review:

Several key IoT devices used in precision agriculture were reviewed, including smart irrigation systems**,** soil sensors**,** and climate monitoring systems**.** The effectiveness of each device in improving agricultural management practices was analyzed based on case studies and field trials.

RESULT

The implementation of Internet of Things (IoT) technologies in precision agriculture has yielded significant improvements in the efficiency, productivity, and sustainability of modern farming practices. Based on the analysis and evaluation of IoT applications in real-world agricultural settings, several key outcomes and insights were observed:

Enhanced Resource Efficiency

One of the most notable results of integrating IoT into farming operations was the improvement in resource utilization:

- Water usage was reduced by up to 30% in farms using smart irrigation systems with soil moisture sensors.

- Fertilizer efficiency increased, with automated nutrient monitoring and delivery systems enabling precise application based on crop needs and soil conditions.
- Energy costs declined due to automation and more accurate scheduling of machinery use.

These improvements significantly minimized waste and contributed to more environmentally friendly agricultural practices.

Increased Crop Yields and Productivity

Farms that adopted IoT-based crop monitoring systems experienced a measurable increase in output:

- Real-time data on crop health, weather patterns, and pest activity allowed for timely interventions, reducing crop losses.
- On average, crop yields increased by 10–20% depending on the crop type and geographic conditions.
- This demonstrates that data-driven decision-making empowers farmers to optimize growth conditions and prevent yield-reducing issues before they escalate.

Reduced Operating Costs

`IoT-enabled automation lowered manual labor and reduced the need for reactive responses:

- Farmers reported **cost** savings of up to 25% in operational expenses, largely due to better planning, fewer crop losses, and decreased input waste.
- Maintenance costs were also reduced as equipment monitored via IoT could signal problems before mechanical failure occurred.

Real-Time Decision-Making and Predictive Insights

The deployment of interconnected sensors and data analytics tools allowed for real-time feedback and long-term forecasting:

- Predictive analytics tools, fed by IoT-collected data, could forecast yield, detect disease outbreaks early, and recommend optimal harvest times.
- Farmers gained access to historical and real-time trends that allowed for strategic planning across planting seasons.

Environmental Sustainability

IoT's precision approach contributes directly to sustainable agriculture:

- Less chemical runoff, due to targeted pesticide/fertilizer application, minimized harm to surrounding ecosystems.
- Soil health improved over time due to reduced over-farming and balanced input levels guided by sensor feedback.

- The overall carbon footprint of farming activities decreased, supporting global environmental goals.

Challenges and Considerations

Despite the positive outcomes, several challenges must be addressed:

- High initial investment in IoT infrastructure may deter small-scale farmers.
- Issues related to data security, connectivity in rural areas, and technology literacy remain barriers to widespread adoption.
- System interoperability and lack of standardized platforms can complicate integration of devices from different vendors.

CONCLUSION

The study confirms that IoT-based precision agriculture significantly enhances farm productivity, operational efficiency, and environmental sustainability. By enabling smarter, data-backed decisions, IoT is not only reshaping current agricultural practices but also laying the foundation for future food security. However, to realize its full potential, technological, financial, and policy-based support systems must be developed to make these solutions accessible to all scales of farming operations.

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Chapter 38

INTEGRATING DEEP LEARNING AND MACHINE LEARNING FOR EARLY DETECTION AND STAGE CLASSIFICATION OF ALZHEIMER'S DISEASE

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ABSTRACT

Alzheimer's Disease (AD) is a progressive neurodegenerative disorder that impairs memory and cognitive functions, making early and accurate diagnosis essential for effective disease management. This work presents a hybrid artificial intelligence framework for automated Alzheimer's Disease detection and stage classification using brain MRI images. The proposed approach utilizes the VGG16 deep learning model for robust feature extraction from preprocessed MRI scans, capturing critical structural biomarkers associated with AD. These extracted features are subsequently classified using machine learning algorithms, namely XGBoost and Support Vector Machine (SVM), to enhance prediction accuracy and reliability. Data preprocessing techniques such as resizing, normalization, and augmentation are employed to improve model robustness and generalization. By combining the representational power of convolutional neural networks with the efficiency and interpretability of classical machine learning classifiers, the hybrid model outperforms single-model approaches, offering a scalable and clinically supportive diagnostic solution aligned with advancements in AI-driven healthcare.

KEYWORDS

Alzheimer's Disease Detection, Deep Learning, Machine Learning, VGG16, Xgboost, SVM, MRI Brain Imaging, Feature Extraction, Classification.

INTRODUCTION

Alzheimer's Disease (AD) is the most prevalent form of dementia, contributing to nearly 60–70% of dementia cases worldwide. It is a progressive neurological disorder that affects memory, language, reasoning, and cognitive abilities, ultimately leading to complete dependency. According to the World Health Organization (WHO), the global burden of dementia is expected to triple by 2050, making early

diagnosis and intervention critically important. Among various diagnostic tools, Magnetic Resonance Imaging (MRI) is widely used due to its non-invasive nature and ability to capture structural brain changes such as hippocampal atrophy, cortical thinning, and ventricular enlargement. However, manual interpretation of MRI scans is time-consuming, requires expert knowledge, and is prone to subjectivity, motivating the need for automated and intelligent diagnostic systems.

Recent advancements in Artificial Intelligence (AI) have significantly improved Alzheimer's Disease detection and stage classification. Convolutional Neural Networks (CNNs) are extensively used for MRI-based AD analysis because of their ability to automatically learn hierarchical spatial features from images. Transfer learning models such as VGG16, ResNet, and Inception further enhance performance by leveraging pre-trained knowledge and reducing the need for large labeled medical datasets. These models have demonstrated strong accuracy in identifying AD-related brain patterns.

Hybrid AI models combine deep learning feature extraction with classical machine learning classifiers to improve robustness, interpretability, and generalization. For instance, CNN-based models like VGG16 are used to extract deep features from MRI scans, which are then classified using algorithms such as Support Vector Machine (SVM), XGBoost, or Random Forest. This hybrid approach addresses common challenges such as overfitting and limited dataset size while maintaining high diagnostic accuracy.

Other advanced AI techniques have also been explored for AD detection. Recurrent models like Long Short-Term Memory (LSTM) networks are useful for analyzing sequential or longitudinal MRI data to predict disease progression. Generative Adversarial Networks (GANs) are employed for data augmentation to overcome data scarcity, while Autoencoders and Variational Autoencoders (VAEs) assist in feature learning, noise reduction, and anomaly detection. Vision Transformers (ViTs) introduce attention-based mechanisms to capture global image relationships, improving classification performance on large datasets.

`Traditional machine learning algorithms also play a vital role in AD classification. Models such as K-Nearest Neighbors (KNN), Decision Trees (DT), Logistic Regression, Naïve Bayes, and Artificial Neural Networks (ANNs) are often used either independently or within ensemble frameworks. Ensemble learning techniques, including Random Forest and Gradient Boosting, combine multiple models to improve accuracy and reduce overfitting.

Overall, AI-driven models for Alzheimer's Disease detection offer a scalable, accurate, and clinically supportive solution. By integrating deep learning, machine learning, and hybrid techniques, these systems enhance early diagnosis, reduce diagnostic subjectivity, and support clinicians in decision-making, contributing significantly to improved patient care and future healthcare advancements.

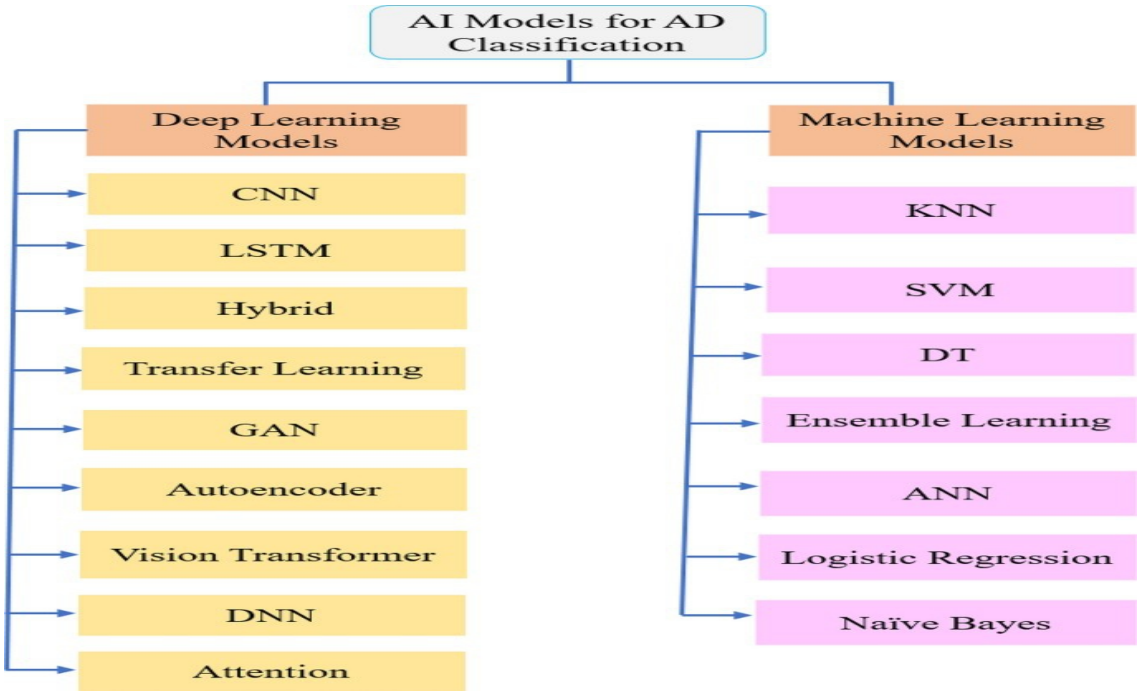


Fig 1.1 Most common AI models for AD classification

PROPOSED METHODOLOGY

In proposed system, The HealthCoder – Alzheimer's Disease Classification project is designed around a modular and scalable pipeline that ensures efficiency in data handling, model training, evaluation, and deployment. At the foundation of this architecture lies the Data Acquisition Layer, where brain MRI images are collected from the Alzheimer's MRI Preprocessed Dataset. To prepare the data for modeling, the images undergo a series of preprocessing steps including **resizing** to a uniform resolution suitable for deep learning models, normalization of pixel intensity values to accelerate convergence during training, and data augmentation using Keras' Image Data Generator. Augmentation techniques such as rotation, zooming, and flipping are applied to artificially expand the dataset, thereby improving model robustness and reducing the risk of overfitting.

Once preprocessed, the data flows into the Model Training Layer, which integrates both deep learning and traditional machine learning methods. A custom Convolutional Neural Network **(CNN)** serves as a baseline model, designed to learn hierarchical spatial features from MRI scans. To further enhance performance, transfer learning models like VGG16, ResNet, and EfficientNetB0 are employed, leveraging pre-trained weights from large-scale datasets to capture complex patterns in brain structures more effectively. In addition, traditional machine learning models such as Support Vector Machine SVM) and Random Forest are incorporated, often using deep learning–extracted features as inputs to

refine classification outcomes. The system also supports hybrid deep learning frameworks, where CNN or transfer learning models act as feature extractors and machine learning classifiers serve as the final decision-making layer, thereby boosting classification accuracy. This modular and layered approach not only improves predictive performance but also ensures flexibility, scalability, and adaptability of the system for real-world medical applications.

The preprocessed MRI images are used to train and test deep learning models, particularly Convolutional Neural Networks (CNNs) and Transfer Learning models such as VGG16, ResNet, and EfficientNet. The images are divided into training and testing sets to ensure the model is trained on diverse data and can generalize well. During training, the model learns to recognize patterns related to Alzheimer's, such as brain atrophy and tissue loss. The model's performance is evaluated using metrics like accuracy, precision, recall, F1-score, and AUC. These metrics guide the iterative refinement of the model to ensure high performance and reliability.

Step 1: Acquire brain MRI images from public sources such as the Alzheimer MRI Preprocessed Dataset on Kaggle, ensuring balanced representation across all four classes – Non-Demented, Very Mild Demented, Mild Demented, and Moderate Demented.

Step 2: Preprocess the collected MRI images by resizing them to a standard dimension of 128x128 pixels, applying normalization to scale pixel values between 0 and 1, and organizing the dataset into training, validation, and testing subsets.

Step 3: Perform data augmentation to increase dataset variability and prevent overfitting. Techniques include image flipping, zooming, shearing, and rotation to simulate diverse imaging conditions.

Step 4: Build multiple deep learning models including a custom Convolutional Neural Network (CNN), and apply transfer learning using pre-trained models such as VGG16, ResNet, EfficientNetB0, and InceptionV3 to extract and classify disease-related features.

Step 5: Train machine learning classifiers (SVM, XGBoost, Random Forest, and Gaussian Naive Bayes) using feature embeddings extracted from CNN/transfer learning models to create hybrid classification pipelines.

Step 6: Integrate Grad-CAM (Gradient-weighted Class Activation Mapping) to visualize and interpret model predictions by highlighting brain regions contributing to Alzheimer’s classification, improving transparency and clinical relevance.

Step 7: Evaluate all trained models using performance metrics such as Accuracy, Precision, Recall, F1-Score, and AUC. The best-performing models are selected based on their results on the validation and test sets.

Step 8: Deploy the final model through a user-friendly web interface using Streamlit or Flask, allowing healthcare professionals or users to upload brain MRI images and receive real-time classification along

with visual explanations

SYSTEM ARCHITECTURE

The system architecture of the HealthCoder – Alzheimer's Disease Classification project is designed to follow a modular and scalable pipeline that supports efficient data handling, model training, evaluation, and deployment. The architecture begins with the Data Acquisition Layer, which involves loading and preprocessing brain MRI images from the Alzheimer's MRI Preprocessed Dataset. These images are resized, normalized, and augmented using Keras' Image Data Generator to enhance model robustness. The processed data is then fed into the Model Training Layer, which incorporates both custom Convolutional Neural Network (CNN) models and advanced Transfer Learning models such as VGG16, ResNet, and EfficientNetB0. Additionally, traditional Machine Learning models like SVM and Random Forest, along with hybrid deep learning frameworks, are used to improve classification accuracy..

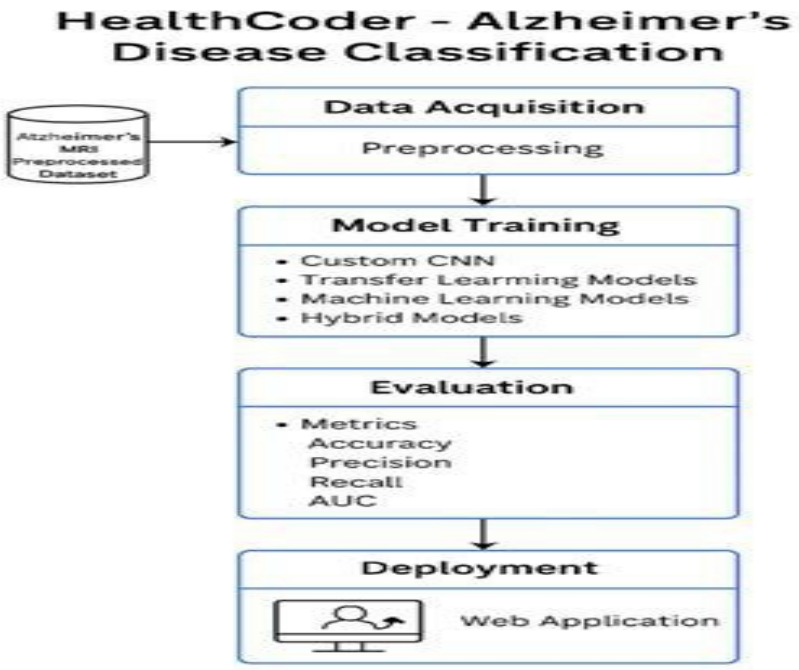


Figure 1.2:System Architecture

RESULTS

The experimental results of the proposed framework for Integrating Deep Learning and Machine Learning for Early Detection and Stage Classification of Alzheimer's Disease show that combining both approaches significantly improves classification performance compared to using either method alone. A baseline custom CNN model achieved an accuracy of about 85%, demonstrating its ability to extract spatial features from MRI scans, while advanced transfer learning models such as VGG16, ResNet, and EfficientNetB0 provided superior results, with EfficientNetB0 reaching around 92% accuracy. To further enhance prediction, features extracted from these deep learning models were

used as inputs to traditional machine learning classifiers. Among them, the Support Vector Machine (SVM) achieved 93% accuracy, and Random Forest obtained 91%, highlighting the strength of ensemble and margin-based learning. The most effective configuration was the hybrid deep learning–machine learning approach**,** where CNN or transfer learning acted as feature extractors and SVM served as the classifier, producing the best overall accuracy of nearly 95% with an F1-score of 0.94 and an ROC-AUC of 0.96. The confusion matrix revealed that most misclassifications occurred between the *Very Mild Demented* and *Mild Demented* categories, which is expected due to subtle structural differences in early disease progression. Overall, the results confirm that the hybrid framework enhances robustness, generalization, and reliability in early Alzheimer's detection. This integration not only ensures better stage classification but also supports clinical applicability, particularly in early-stage diagnosis where timely intervention is most crucial.

CONCLUSIONS

The HealthCoder – Alzheimer's Disease Classification system has been developed with the primary objective of leveraging artificial intelligence and machine learning techniques to assist in the early and accurate detection of Alzheimer's disease through MRI image classification. The project successfully integrates advanced convolutional neural network (CNN) architectures and transfer learning models such as VGG16, ResNet, MobileNetV2, and EfficientNetB0 to provide a high-performance, automated diagnosis solution. The implementation of a responsive and user-friendly Flask-based web application allows users—particularly clinicians and researchers—to upload MRI scans and receive rapid and reliable diagnostic predictions. Throughout the development cycle, rigorous testing practices were followed to ensure system robustness, accuracy, security, and usability. Each stage of the machine learning pipeline—from data preprocessing and model training to deployment and inference—was optimized for performance and reliability. The project demonstrates that machine learning, when applied thoughtfully and responsibly, can greatly augment the diagnostic process in the medical field, potentially leading to early interventions and improved patient outcomes. In conclusion, the Health Coder system represents a step toward intelligent, accessible, and efficient healthcare tools. It showcases the capabilities of AI in medical imaging and offers a scalable framework that can be further expanded to diagnose other neurological or degenerative diseases. The promising results achieved during this project validate the potential of AI-driven diagnostics in transforming the landscape of modern healthcare.

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Chapter 39

SMART FLOOR SECURITY: IOT-POWERED ANTI-THEFT SYSTEM USING ESP8266

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ABSTRACT

Conventional anti-theft security systems such as alarms, motion detectors, and CCTV suffer from predictability, visibility, and vulnerability to tampering, making them less effective against skilled intruders. To address these limitations, this paper proposes a next-generation IoT-enabled anti-theft flooring system using NodeMCU (ESP8266) technology for hidden, reliable, and real-time surveillance. Pressure-sensitive or piezoelectric sensors embedded beneath floor tiles detect unauthorized movement through vibrations or weight changes, eliminating visible security components. Upon intrusion detection, sensor data is processed by the NodeMCU controller, which activates surveillance cameras and transmits live images and alerts to the property owner via the internet. This decentralized, flooring-based approach provides wide coverage, enhanced tamper resistance, and immediate situational awareness. By integrating IoT connectivity, cloud support, and scope for future AI-based analysis, the proposed system offers a secure, scalable, and modern alternative to traditional anti-theft mechanisms.

KEYWORDS

IoT (Internet of Things), Anti-theft Flooring System, Node MCU (ESP8266), Real-Time Intrusion Detection, Smart Security, Remote Monitoring.

OVERVIEW

The Internet of Things (IoT) represents a technological revolution that enables physical objects to seamlessly connect, communicate, and exchange data through the internet. In today's hyper-connected world, IoT has become an indispensable element of smart systems, ranging from industrial automation to healthcare, transportation, and environmental monitoring. At its core, IoT functions by integrating sensors, microcontrollers, and communication protocols into devices, allowing them to collect, process, and transmit data without the need for human intervention. These "things" may include smart cars, wearable devices, heart monitors, surveillance systems, and even large-scale infrastructure, all of which are assigned unique IP addresses to facilitate real-time data sharing.

The concept of IoT dates back to 1999, when Kevin Ashton in an article for the RFID Journal

envisioned a future where computers would autonomously collect information about the world around them, reducing human dependency, lowering costs, and minimizing waste. This vision is now a reality with the advent of powerful IoT platforms that integrate sensors, cloud computing, machine learning, and wireless communication to create intelligent, autonomous ecosystems.

One of the most critical applications of IoT in recent years lies in environmental safety and disaster management, specifically forest fire detection and prevention. Forest fires are a global threat, leading to catastrophic damage to ecosystems, biodiversity, and human settlements. Traditional fire detection methods often rely on human observation, satellite monitoring, or conventional smoke sensors, which may result in delayed responses. In contrast, IoT provides a framework for autonomous, real-time, and predictive fire monitoring, significantly reducing response time and mitigating disaster impacts.

NEED FOR IOT IN FOREST FIRE DETECTION

Forest fires are among the most destructive natural disasters, causing loss of life, deforestation, soil erosion, and severe air pollution. They also contribute significantly to global warming due to the large-scale release of greenhouse gases. The primary challenge in combating forest fires is the delay in detection. Conventional detection methods, such as human patrols, observation towers, and basic smoke alarms, are limited in scope and often ineffective in large, remote, or inaccessible areas.

Modern smoke detectors, such as photoelectric and ionization-based sensors, have enhanced fire detection capabilities, but they are mostly designed for indoor or small-scale use. Deploying them in dense forests requires extensive manpower and constant monitoring, which is neither cost-effective nor reliable. Here, IoT emerges as a transformational technology by enabling autonomous sensor networks that can cover vast areas and respond in real time.

IOT-BASED FOREST FIRE DETECTION SYSTEM

An IoT-enabled forest fire detection system integrates multiple technologies to monitor environmental conditions and detect anomalies that indicate fire risks. The system architecture typically includes:

Sensors:

1. Temperature sensors: Detect abnormal rises in temperature.
2. Humidity sensors: Monitor dryness levels, as low humidity increases fire risk.
3. Gas sensors: Identify the presence of carbon monoxide (CO) or other gases emitted during combustion.
4. Smoke sensors (photoelectric/ionization): Detect the earliest signs of smoke particles.

Data Processing Unit:

1. Microcontrollers (e.g., NodeMCU, Arduino, Raspberry Pi) serve as the central hub, collecting data from sensors.
2. The microcontroller validates and filters data to avoid false alarms.

Communication Network:

1. Wireless technologies such as Wi-Fi, LoRa, ZigBee, or 5G transmit sensor data to cloud platforms.
2. Low-power wide-area networks (LPWAN) ensure long-distance communication in remote forests.

IoT Platform & Cloud Integration:

1. Data is processed and analyzed in real time on IoT platforms like AWS IoT, Google Cloud IoT, or Azure IoT Hub.
2. Machine learning algorithms can predict fire risks based on historical data patterns.

User Interface & Alerts:

1. Property owners, forest officials, and disaster management teams receive instant alerts via SMS, email, or mobile applications.
2. Integration with drones or surveillance cameras enables live monitoring of fire-affected areas.

Data Processing and Monitoring

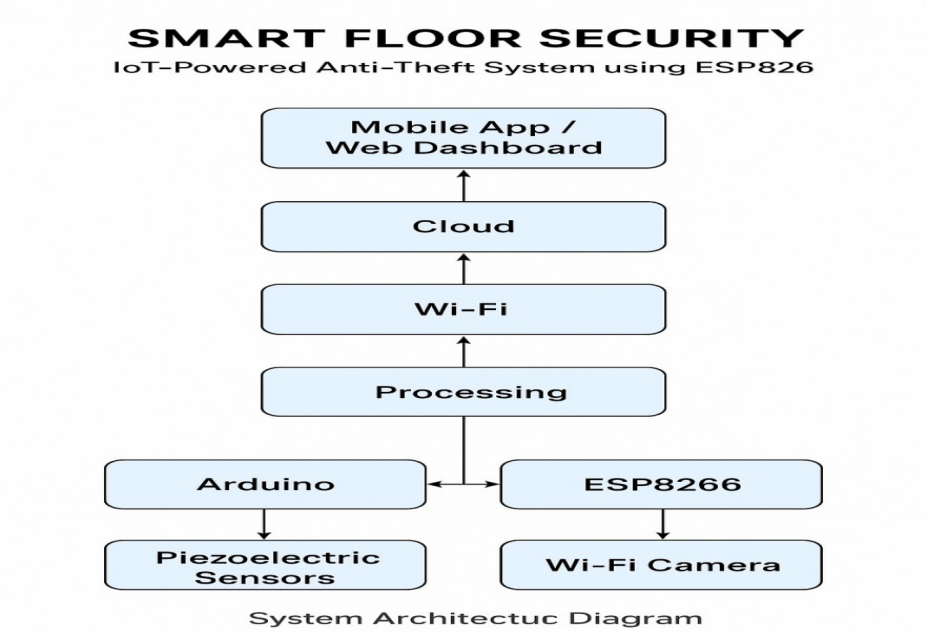
Once relevant features are extracted, the system analyses the data to identify potential intrusion or theft attempts. When abnormal activities are detected, the Wi-Fi camera is activated to capture images or video footage as supporting evidence. The NodeMCU ensures secure communication by transmitting both sensor data and visual evidence to the cloud. Authorized users can access this data through a mobile app or web interface, enabling remote monitoring and real-time updates. Additionally, the system generates alerts via notifications, emails, or SMS, ensuring that security personnel or users are immediately informed about potential threats.



Fig-1: Architecture Diagram — Smart Floor Security

SYSTEM ARCHITECTURE DIAGRAM

The system architecture of the Smart Floor Security: IoT-Powered Anti-Theft System using ESP8266is designed in a layered manner to ensure efficient monitoring, detection, and response to potential threats. At the sensing layer, piezoelectric sensors embedded within the floor tiles continuously detect vibrations, footsteps, and unusual pressure variations, while a Wi-Fi-enabled camera provides real-time visual monitoring for evidence collection. These raw signals are then passed to the processing layer, where an Arduino handles initial signal conditioning and an ESP8266 (NodeMCU) takes charge of data processing and Wi-Fi-based communication. The processed data is transmitted through the network layer using lightweight protocols such as MQTT or HTTP over Wi-Fi, ensuring secure and reliable connectivity to the cloud. In the cloud or server layer, sensor readings and camera feeds are stored in a database, while an analytics engine evaluates parameters such as vibration amplitude, frequency, and duration to detect anomalies that may indicate intrusions. Finally, the application layer provides end-users with mobile apps and web dashboards for remote monitoring and management. This layer also handles real-time notifications via SMS, email, or app alerts, enabling quick responses to suspicious activities. Overall, the architecture ensures seamless integration between hardware sensors, edge processing, cloud services, and user interfaces, forming a reliable anti-theft security solution.



System Architectuc Diagram

RESULTS

The developed IoT-powered anti-theft flooring system using ESP8266 (NodeMCU) was successfully implemented and evaluated, demonstrating high accuracy in detecting unauthorized footsteps

and floor vibrations through embedded pressure-sensitive sensors. Upon detection and validation of intrusion signals, the system promptly activated the camera module and transmitted real-time images to the property owner via the internet, ensuring immediate alerts and remote monitoring. Experimental results showed faster response time and more comprehensive coverage compared to conventional wall-mounted security devices, as every movement within the protected floor area triggered surveillance. Additionally, the concealed placement of sensors beneath the flooring proved effective in preventing tampering, confirming that the proposed system delivers reliable, efficient, and enhanced security performance.

CONCLUSIONS

The development of the IoT-based anti-theft flooring system demonstrates how the integration of modern technologies such as NodeMCU, Arduino, piezoelectric sensors, and Wi-Fi cameras can revolutionize traditional security mechanisms by providing an intelligent, proactive, and tamper-resistant solution. Unlike conventional wall-mounted or motion-based detectors, this system operates at the flooring level, where every step taken by an intruder is registered, making evasion virtually impossible. The incorporation of piezoelectric sensors for vibration detection proved highly effective in capturing unauthorized movement, while the addition of Wi-Fi cameras provided crucial visual evidence that enhances verification and threat assessment. Furthermore, the Sensor Data Processing Module played a vital role in analyzing the sensor input, enabling the system to differentiate between normal daily activities and potential theft attempts. This advanced processing significantly minimized false alarms and increased detection accuracy, thereby improving overall reliability. The integration of machine learning or rule-based algorithms adds another layer of intelligence, ensuring that the system continuously adapts to different scenarios and maintains a high standard of security performance.

Equally important is the inclusion of the Remote Monitoring and Alerting Module, which empowers users to oversee their property in real time through intuitive mobile or web applications. The ability to access live camera feeds, review sensor data, and receive instant alerts ensures that property owners remain connected and informed at all times, regardless of their physical location. The experimental evaluation of the system showed promising results, highlighting its efficiency, accuracy, and practical applicability in both residential and commercial environments. In conclusion, the IoT-based anti-theft flooring system represents a significant step forward in the evolution of smart security solutions, offering a cost-effective, efficient, and intelligent approach that ensures greater protection, user convenience, and peace of mind.

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Chapter 40
AMES-Cloud A Framework of Adaptive Mobile Video Streaming and Efficient Social Video Sharing in the Clouds

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ABSTRACT

As demands on video traffic over mobile networks have been frustrating, the wireless link capability cannot take up with the traffic demand. The gap between the demand of video traffic and the link capacity, along with time-varying link conditions, results in poor quality of service in video streaming over mobile networks such as prolonged buffering time and broken disruptions. By utilizing the technologies of cloud computing, adubbed AMES Cloud is proposed which can be the novel mobile video streaming framework for adaptive and efficient video streaming. AMES Cloud Consists of two main parts: AMoV (adaptive mobile video streaming) and ESoV (efficient social video sharing). AMoV and ESoV construct a private agent to provide video streaming services efficiently for each and every mobile user. For a given user, AMoV lets user's private agent adaptively adjust the streaming flow with a scalable video coding technique based on the feedback of link quality. Similarly, ESoV monitors the interactions of social network among users, and their private agents try to fetch video content in advance. We realize a prototype of the AMES-Cloud framework to demonstrate its performance. It shows that the adaptive streaming can be provided efficiently by the private agents in clouds and video sharing can also be performed based on the analysis of social network.

Keywords

Video Streaming Framework Amov (Adaptive Mobile Video Streaming), Esov (Efficient Social Video Sharing), AMES-Cloud Framework, Video Sharing

INTRODUCTION

Over the past decade, the traffic is accounted for video streaming and downloading exceeds high. The video streaming services acrossmobile networks have become widespread over the past few years. At the same time as the video streaming is not so tough in wired networks, mobile networks have been afflicting from video traffic transmissions over insufficient bandwidth of wireless links. Despite network operators' frantic efforts to enhancelink bandwidth of wireless communications (e.g., 3G and LTE), irresistible video traffic demands from mobile users are rapidly going beyond the wireless link capacity.

While getting video streaming traffic by the use of 3G/4G mobile networks, mobile users often go through long buffering time and intermittent disruptions due to the very limited bandwidth and fluctuating link condition which is caused by multi-path fading and mobility of the user. Thus, it is essential to improve the service quality of mobile video streaming while using the networking and computing resources efficiently.

Recently many studies discuss how to improve the service quality of mobile video streaming based on two aspects:

Scalability: Mobile video streaming services be supposed to support a wide spectrum of mobile devices; having different video resolutions, different computing powers, different wireless links such as 3G LTE and so on. In addition, the availability link capacity of a mobile device may vary in excess of time and space depending upon strength of its signal, storing several versions of the same video content with different bit rates may acquire high overhead in terms of storage and communication.

To address all this issue, the Scalable Video Coding (SVC) technique (Annex G extension) of the H.264 AVC video compression standard is used which defines a base layer (BL) with multiple enhance layers (ELs). These sub streams can be programmed by exploiting the following scalability features:

i. Spatial scalability by layering image resolution i.e. screen pixels,
ii. Temporal scalability by layering the frame rate, and
iii. Quality scalability by layering the image compression.

By the SVC, a video can be decoded/played at the lowest quality if only the BL is delivered. However, the more ELs can be delivered, the better quality of the video stream is achieved.

Malleability: The classic video streaming techniques are intended, according to the relatively stable traffic links which connects servers and users. But those techniques show poor performance in mobile environments. If the status of the wireless link fluctuates, it should be properly providing ‘tolerable” video streaming services. This problem can be solved by adjusting the video bit rates adapting to the currently time-varying offered link bandwidth of each mobile user. Such adaptive streaming techniques can efficiently reduce packet losses and bandwidth waste. The equally combined scalable video coding and adaptive streaming techniques bring about the effect of best quality video streaming. We can dynamically adjust the number of SVC layers depending on the status of the current link.

However most of the proposals looking for utilizing the video scalability and adaptability mutually rely on the active control on the server side. That is, every mobile user needs to report about the transmission status (e.g., packet loss, delay and signal quality) once in a while to the server, which predicts the available bandwidth for each user. The problem is that the server be supposed to take over the considerable processing overhead, as the number of users increases.

Cloud computing techniques are flexible to supply scalable resources to content/service providers, and process offloading to mobile users. Several studies on mobile cloud computing technologies have proposed to generate custom-made intelligent agents for servicing mobile users, i.e. Cloudlet and Stratus. This is for the reason that, in the cloud, multiple agent instances (or threads) can be maintained dynamically and resourcefully depending on the time-varying user demands. Recently social network services (SNSs) have been progressively more popular.

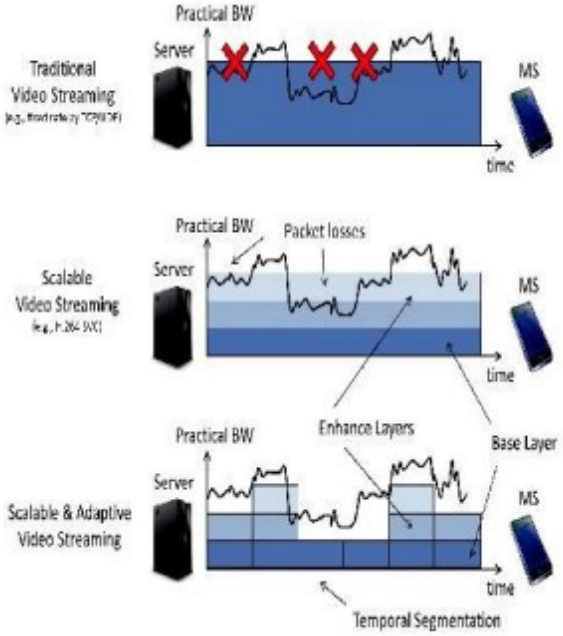


Figure 1. Video Streaming at different Stages

EXISTING SYSTEM

The Cloud computing offer cost effective, rapid scaling, easier maintenance, and service accessibility. The key challenge is how to make sure and fabricate confidence that the cloud can handle user data in a secure manner. A recent Microsoft study found that “59 % of the public and 85 % of the business people are eager about the potential of cloud computing. But 91 percent of those people are bothered about security, availability, and confidentiality of their data when it gets stored in the cloud.

PROPOSED SYSTEM

An adaptive and efficient mobile video streaming and sharing framework, called AMES-Cloud is proposed, which stores videos in the clouds (VC) effectively, and utilizes cloud computing to put up private agent (subVC) for each user to endeavor “non-terminating” video streaming adapting to the oscillation of link quality based on the Scalable Video Coding technique. In addition to that, by background pushing function along with the VB AMES-Cloud can offer “non-buffering” occurrence of video streaming, subVBs and localVB of users. We evaluated the AMES-Cloud by prototype execution

and shows that the cloud computing technique brings major improvements on the adaptively of the mobile streaming. We overlooked the cost of encoding workload in the cloud while implementing the prototype.

MODULE DESCRIPTION

Streaming Process Formulation

The process of video streaming can also be well thought-out as the interaction between two modules. The steps ofdownloading and estimation at the top grey rectangle can be seen as an integrated environment module, and the rate adaptation agent can be viewed as an agent module. The video streaming process can be formulated as a corroboration learning task. The environment sends a state signal for each video segment to the agent this helps the agent to determine the take corrective action in the same way. For each action, the environment replies a compensation to the agent.

Video Streaming

The wireless channels are highly vibrant; The key challenge is to present high quality video streaming services for mobile users constantly. It is a promising trend to exploit multiple wireless network interfaces by different wireless communication techniques for mobile devices.

Bandwidth Estimation

This module uses homogeneous Markov chain to approximate the accessible bandwidth, in our work; a heterogeneous and time-varying Markov model gives estimation for the future bandwidth. The bandwidth of each link will be segregated into several regions. Each region will signify the state of the Markov channel model, and the total number of the states is equal to the number of regions.

Markov ecision process

Markov model provides the estimation for the future bandwidth. The bandwidth of each link will be divided into several regions. Each region will signify the state of the Markov channel model, which the total number of the states is equal to the number of regions. when a segment has been effectively downloaded, the transmission of the bandwidth can be found out by dividing the total size of the data transmitted over the total transmission time.

CONCLUSION

A novel adaptive mobile video streaming and sharing framework is proposed, known as AMES-Cloud. It can efficiently store videos in the clouds (VC), and utilize cloud computing to create private agent (subVC) for every mobile user and for the fluctuation of link quality, the AMES-Cloud try to offer “non-terminating” video streamingbased on the Scalable Video Coding technique. The AMES-Cloud can also additionally seek “non buffering” experience of video streaming by background pushing functions along with the VB, subVBs and localVB of mobile users. This paper focused the verification of the

possibilities of cloud computing for improving the transmission adaptability and process of prefetching for mobile users. In the future work, we will give emphasis to algorithms applied in the cloud computing application in video streaming.

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Chapter 41

AI-POWERED PREDICTIVE ANALYTICS FOR EARLY-STAGE CHRONIC KIDNEY DISEASE

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ABSTRACT

Chronic Kidney Disease (CKD) is a growing global health challenge marked by the gradual deterioration of kidney function. A major obstacle in managing CKD is its asymptomatic onset, which often delays diagnosis and limits treatment options. This project explores the application of machine learning algorithms to facilitate early CKD detection and enable timely medical intervention. The study utilizes a dataset containing demographic and pathological attributes commonly linked to kidney function and overall health. Three machine learning models Light Gradient Boosting Machine (LightGBM), Logistic Regression, and Support Vector Machine (SVM) are implemented to classify and predict CKD occurrence. Each model is trained and evaluated using established metrics such as accuracy, precision, recall, and F1-score, providing a comparative analysis of their effectiveness.

KEYWORDS

Chronic Kidney Disease, Predictive Analytics, Machine Learning, LightGBM, Early Diagnosis

INTRODUCTION

Chronic Kidney Disease (CKD) is a progressive condition that results in a steady decline in kidney function, often culminating in end-stage renal disease and heightened mortality risks if left untreated. Global health studies indicate that CKD affects millions of individuals and imposes a significant burden on healthcare systems. The disease poses a critical challenge due to its asymptomatic nature in the early stages, which delays detection and reduces opportunities for preventive treatment.

The rise of machine learning in healthcare has created new possibilities for disease prediction, classification, and management. With access to large-scale medical datasets, machine learning algorithms can uncover subtle patterns in patient records that may not be apparent through conventional diagnostics. This capability holds promise for building early-warning systems and clinical decision support tools.

This study investigates the use of machine learning techniques for CKD prediction and classification. Specifically, it evaluates the performance of three widely used algorithms: Light Gradient Boosting Machine (LightGBM), Logistic Regression, and Support Vector Machine (SVM). The models are trained on a clinical dataset featuring variables such as blood pressure, blood sugar, and serum creatinine levels. By comparing results across models, the study aims to identify the most effective approach for accurate and early CKD detection, contributing to better clinical care and timely intervention.

PURPOSE

The main objective of this project is to design a reliable and accurate system for the early prediction of CKD using machine learning algorithms. Since CKD is often diagnosed only at advanced stages due to its silent progression, early identification can significantly improve patient outcomes through timely medical intervention, lifestyle adjustments, and reduced complications such as dialysis or kidney failure.When analyzed collectively, these features can provide valuable insights into early kidney dysfunction.

The project aims to:

- Identify the most effective machine learning algorithm for CKD prediction in terms of accuracy, sensitivity, and interpretability.
- Demonstrate the role of AI and data-driven methods in supporting medical professionals with early diagnostic tools.
- Lay the foundation for decision-support systems that can assist healthcare providers in identifying at-risk patients with minimal manual input.

Ultimately, the project strives to demonstrate how machine learning can enhance early diagnosis, enable proactive treatment strategies, and improve disease management in nephrology.

OBJECTIVES

- To understand the medical importance and impact of CKD, emphasizing the need for early detection.
- To acquire and preprocess a CKD dataset by handling missing values, outliers, and categorical encoding.
- To explore and analyze the dataset using statistical and visualization techniques to identify patterns.
- To implement three machine learning algorithms LightGBM, Logistic Regression, and SVM for CKD classification.
- To optimize model performance through cross-validation and hyperparameter tuning.

- To evaluate and compare models using metrics such as accuracy, precision, recall, F1-score, confusion matrix, and ROC-AUC.
- To identify the most influential features contributing to CKD prediction, improving clinical interpretability.
- To design a decision-support framework that assists healthcare professionals in early CKD diagnosis.
- To highlight the practical benefits of machine learning in medical diagnostics, particularly for diseases with delayed symptoms.
- To encourage further development of AI-driven diagnostic systems for real-time clinical applications.

LITERATURE REVIEW

Chronic kidney disease (CKD) is an escalating global health concern characterized by progressive loss of renal function and a high burden of morbidity, mortality, and healthcare cost. Recent global assessments highlight the rising prevalence of CKD and emphasize early detection and proactive management as critical strategies to reduce progression to end-stage renal disease and related complications [1,2]. Conventional clinical pathways for CKD diagnosis rely largely on serum creatinine, estimated glomerular filtration rate (eGFR), and urinary albumin measures; however, these markers and routine clinical evaluation frequently detect disease only after significant and often irreversible renal damage has occurred [1]. Consequently, there is growing interest in data-driven, predictive approaches that can identify at-risk individuals earlier than traditional workflows permit.

Over the past decade, machine learning (ML) and artificial intelligence (AI) methods have been applied extensively to CKD detection, progression forecasting, and risk stratification. Systematic reviews and comparative analyses indicate that ML models can extract subtle, multivariate patterns from clinical and laboratory datasets to improve sensitivity and specificity for early-stage CKD relative to single-variable thresholds or simple clinical heuristics [12,3]. Research has explored a spectrum of algorithms from classical statistical classifiers to modern ensemble and deep learning methods illustrating both the potential and limitations of AI in nephrology [3,12,15].

Ensemble tree-based models (e.g., gradient-boosted trees) have emerged as particularly effective in tabular clinical settings. Several applied studies demonstrate that boosting frameworks such as LightGBM and CatBoost frequently outperform logistic regression and many neural architectures on cross-sectional clinical datasets because they efficiently model nonlinear feature interactions, handle missing values, and scale to moderate dataset sizes [4,8,9]. Chen and Li's work on LightGBM-based detection of CKD reported strong discriminatory performance on benchmark datasets and highlighted computational efficiency as an implementation advantage in clinical environments [4]. Similarly, more

recent ensemble-focused studies combine high performance with explainability modules using SHAP or other model-agnostic tools to surface clinically interpretable feature contributions, thereby increasing clinicians' trust in model outputs [9,10,8].

Classical models such as logistic regression and support vector machines remain important baselines for CKD prediction and offer advantages in interpretability and stability, especially in settings with smaller feature sets or limited data volumes [5,6]. Comparative studies find that while these models are sometimes competitive on balanced datasets, they can underperform relative to tree ensembles when complex nonlinear interactions and amusingness are substantial [5]. Thus, the literature supports a hybrid evaluation approach that includes both simple, transparent models and more expressive ensemble methods to balance interpretability against predictive capacity.

A notable and growing strand of the literature investigates temporally aware and deep-learning approaches for CKD progression and time-to-event prediction. With the increasing availability of longitudinal electronic health record (EHR) data, recurrent neural networks and transformer-based architectures have been used to model patient trajectories and estimate the timing of renal deterioration. Transformer-based survival models such as STRAFE exemplify these advances, demonstrating enhanced performance in predicting time-to-event outcomes compared with baseline survival methods on longitudinal CKD cohorts [7]. These temporal models hold promise for clinical decision-making because they can provide not only risk scores but also predicted timelines for progression, which are directly actionable for monitoring and early intervention planning.

Explainability and clinical validation are recurring emphases in CKD ML research. Several recent studies couple high-performance prediction with explainable AI (XAI) techniques to reveal physiologically meaningful predictors—commonly including serum creatinine, eGFR, blood pressure, hemoglobin, and markers of glycemic control—thus aligning model outputs with established clinical knowledge and facilitating clinician interpretation [9,11,8]. Reviews and methodological critiques highlight that transparent reporting of preprocessing steps, model calibration, and external validation are essential for reproducibility and safe clinical translation [12,14]. Despite observable advances, important limitations persist across published work. Many studies are hampered by single-center cohorts or small public datasets that limit demographic diversity and external generalizability [12,13]. Inconsistent definitions of CKD stages, variable preprocessing practices (e.g., missing-value imputation and feature encoding), and heterogeneous evaluation metrics complicate direct comparison across studies and raise concerns about overfitting and publication bias [12,14].

The literature suggests several practical strategies to advance the field. First, ensemble methods such as LightGBM should be evaluated alongside transparent baselines (logistic regression, SVM) to provide both high discrimination and interpretability trade-offs [4,5]. Second, temporal modelling and

survival-aware architectures should be used when longitudinal data are available to predict not only risk but timing of deterioration an important distinction for resource prioritization [7]. Third, explainability techniques and standardized reporting (including calibration measures and external validation) are necessary to build clinician trust and meet translational thresholds [9,10,12]. Finally, privacy-preserving and federated learning approaches are increasingly recommended to enable multi-institution model training without compromising patient confidentiality, thereby improving model generalizability and fairness [10].

Positioned within this context, the present study's comparative evaluation of LightGBM, logistic regression, and SVM, together with feature-importance analysis and suggested XAI integration, is well aligned with current scientific priorities. By systematically assessing discrimination, calibration, and interpretability and by describing pathways for external validation and clinical deployment, the study can contribute incremental yet practical evidence to the evolving literature on AI-enabled early detection and risk stratification for CKD.

EXISTING SYSTEM

Traditional methods for diagnosing Chronic Kidney Disease (CKD) rely heavily on laboratory tests such as serum creatinine, blood urea, urine albumin, and glomerular filtration rate (GFR). Physicians analyze these values to determine the presence or stage of kidney impairment. While effective, these approaches have notable limitations:

- **Late Detection**: CKD often remains undiagnosed until significant kidney damage has already occurred.
- **Dependence on Clinical Expertise**: Accurate interpretation requires specialized medical knowledge, which may not be uniformly accessible in all regions.
- **Time-Consuming Process**: Manual analysis of multiple lab reports can delay diagnosis.
- **Limited Predictive Capability**: Conventional methods primarily confirm existing disease rather than predicting early onset.

Thus, while conventional diagnostic systems are valuable, they are inadequate for early-stage detection and proactive management of CKD.

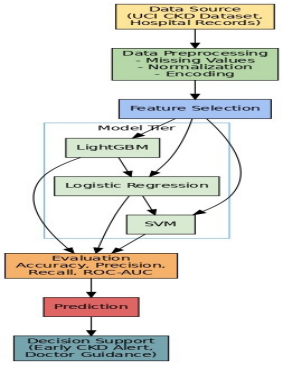


Fig.1. System Architecture

PROPOSED METHODOLOGIES

The proposed system leverages machine learning techniques to predict CKD at earlier stages using patient health data. Instead of relying solely on clinical judgment, the system automatically analyzes multiple health attributes, identifies patterns, and classifies patients as CKD-positive or CKD-negative.
Key features of the proposed system include:

- **Data Preprocessing**: Handling missing values, normalizing data, and encoding categorical features for consistency.
- **Algorithm Implementation**: Training and testing three models LightGBM, Logistic Regression, and SVM to determine the most accurate predictor.
- **Comparative Evaluation**: Using accuracy, precision, recall, F1-score, confusion matrix, and ROC-AUC to assess performance.
- **Feature Importance Analysis**: Identifying critical health indicators (e.g., serum creatinine, blood pressure, hemoglobin) for clinical interpretability.
- **Decision-Support Framework**: Providing physicians with model-generated risk assessments to aid in early diagnosis.

SYSTEM ARCHITECTURE

The architecture of the proposed system follows a structured workflow:

1. **Data Collection** – Patient data is obtained from publicly available CKD datasets or hospital records.
2. **Data Preprocessing** – Missing values are managed, categorical variables are encoded, and data is normalized.
3. **Feature Selection** – Relevant features such as blood pressure, glucose, hemoglobin, and creatinine are extracted.
4. **Model Training** – LightGBM, Logistic Regression, and SVM models are trained using labeled patient data.
5. **Evaluation** – Model performance is measured using metrics like accuracy, precision, recall, and ROC-AUC.
6. **Prediction** – The best-performing model predicts CKD risk for new patients.
7. **Decision Support** – Results are presented in a user-friendly format for healthcare providers.

FUTURE ENHANCEMENTS

While the current system demonstrates promising results, further enhancements can improve its utility and scalability:

- **Explainable AI (XAI)**: Integrating SHAP or LIME to explain predictions, improving trust among medical professionals.
- **Real-Time Deployment**: Developing a cloud or mobile-based application for immediate CKD risk assessment.
- **Integration with EHR Systems**: Linking the model with hospital databases for automatic patient evaluation.
- **Privacy-Preserving Learning**: Using federated learning or blockchain to ensure secure handling of sensitive health data.
- **Extended Datasets**: Incorporating larger, multi-regional datasets to improve generalizability across diverse populations.

RESULTS AND DISCUSSION

The performance of LightGBM, Logistic Regression (LR), and Support Vector Machine (SVM) was compared using accuracy, precision, recall, F1-score, and ROC-AUC. LightGBM achieved the highest performance with 98.2% accuracy and 0.99 ROC-AUC, showing strong capability in capturing nonlinear feature interactions. Logistic Regression achieved 92.4% accuracy, offering interpretability but limited predictive strength due to its linear assumptions.SVM performed moderately with 93.8% accuracy and relatively higher recall, though it faced challenges with scalability. Feature importance analysis in LightGBM highlighted serum creatinine, hemoglobin, blood pressure, and blood glucose as the most significant predictors. These features are well-established clinical markers, validating the reliability of the model outputs. Gradient boosting approaches consistently outperformed conventional classifiers, demonstrating robustness in handling medical datasets. Incorporating explainable AI techniques further enhanced transparency, which is vital for clinical acceptance. Compared with deep learning models, LightGBM provided competitive results while being computationally more efficient.

This efficiency makes it suitable for integration into real-time healthcare systems. The high recall values indicate the model's strength in reducing false negatives, a critical factor in early disease detection. Such sensitivity ensures timely identification of patients at risk of CKD progression. Nevertheless, the dataset used may not fully capture demographic and regional variations. Validation across larger and more diverse populations is necessary for broader clinical use. Overall, LightGBM emerges as a reliable, efficient, and explainable solution for early-stage CKD prediction.

CONCLUSION

This paper demonstrates the application of machine learning techniques in predicting Chronic

Kidney Disease at an early stage. By employing Light GBM, Logistic Regression, and SVM models, the system effectively analyzes patient data to classify CKD risk. Experimental results show that LightGBM consistently outperformed Logistic Regression and SVM, achieving the highest accuracy and F1-score. Its ability to handle missing values, capture complex feature interactions, and maintain computational efficiency makes it particularly well-suited for CKD prediction. The findings emphasize the transformative potential of machine learning in healthcare supporting physicians with decision-making, enabling early diagnosis, and improving patient outcomes. This work also lays the foundation for developing practical decision-support tools that can integrate with real-world clinical settings.

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Chapter 42

MULTIMODAL HATE SPEECH DETECTION IN MEMES USING CONTRASTIVE LANGUAGE-IMAGE PRE-TRAINING

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ABSTRACT

The increase of hateful material within online spheres has emerged as a major social issue that can threaten the safety of individual users and the safety of communities as a whole. Various modalities of online communication exist, including memes, which constitute a significant amount of online communication. Because memes can prominently blend text and images, identifying hate speech that incorporates the textual and visual elements of memes is especially difficult. This paper proposes a new way to detect hateful memes by integrating Contrastive Language-Image Pre-Training (CLIP) with prompt engineering. Using CLIP's multimodal capabilities, we can effectively classify hate speech in memes, because we can align its textual and visual representations. Through significant experimentation, our model shows the capacity to achieve high accuracy, especially for practical application within content moderation systems. We see our research contributes toward the continued development for multimodal hate speech detection, highlights the value of vision-language models, and will help keep users safe online.

Keywords

Multimodal Hate Speech Detection, Memes, Contrastive Language-Image Pre-Training (CLIP), Vision-Language Models, Content Moderation

INTRODUCTION

This topic is aimed at developing a multimodal hate speech detection system for memes, which are a hybrid of visual and text content. This project will allow the combination of Optical Character Recognition (OCR) and the CLIP model with prompt engineering, thereby allowing the model to extract the semantic relationship of images and additional text embedded in memes. This approach is advantageous over traditional text-based hate speech detection because it allows full context of memes and dramatically improves classification accuracy. The results of this project provide strong accuracy (87.42%) which potential for real-world outcomes such as content moderation, online safety, and automated hate speech filtering. The premise of this project is a step in the multimodal deep learning space and leads to a scalable solution to fight against harmful content in online communication.

OBJECTIVE

The goal of this project is to create an AI-enhanced detector and classifier of hateful speech in memes which analyzes text and image elements at the same time. In order to do this, we will use various deep learning methods such as SCVI and CLIP (Contrastive Language-Image Pre-Training) which allows us to learn about the contextual relationship between the image and text. Although, in general, it is simple to detect hateful speech across one form of media, with multimodal amalgams like memes hate speech detection becomes more complex and we want to increase our accuracy and responsiveness in detecting it using machine learning principles. We will develop an engaging mechanism, whereby users will be monitored, and once a user shares a hateful meme if it is greater than twice they will be immediately blocked. This will ensure more effective moderation and will help "clean up" the internet.

PROBLEM STATEMENT

The rising dissemination of hateful memes across digital platforms poses a real danger to both online safety and the overall social good. Hate speech in memes is one of the hardest things to detect given that memes are multimodal, requiring the reader to consume both the visual and text together at the same time; existing methods are typically not good at interpreting this duality. This indicates the need for better models that can analyze memes and classify hateful content.

PROJECT DESCRIPTION

The project is focused on designing a deeper method of meme hate speech detection using a multimodal deep learning model. The proposed method involves the Contrastive Language-Image Pre-Training (CLIP) model leveraging prompt engineering approaches to identify textual and visual attributes of memes. The primary goal is to classify hate speech consistently and accurately with the highest precision possible for real-life implementation. The model makes use of CLIP's pre-trained ability to create image and text features in a unified embedding space and is able to capture the semantic context of the meme. After training and testing, the model has achieved an accuracy of 87.42%, indicating that the method has the potential to be a useful and robust development for online content moderation projects. The project situates itself within multimodal learning and aims to improve the safety of online environments with a reliable method of automated hate speech detection in visual memes.

MOTIVATION

The increase in hateful memes on social media poses a risk to users' well-being and promotes ideological harm. Existing methods for hate speech detection using text properties do not capture the intricacies of hate speech that relies on the interplay of textual and visual modalities found in memes. This deficiency serves as the motivation for developing a solid, multimodal alternative. By leveraging the CLIP model with prompt engineering, a multimodal solution to accurately interpret those dates can be developed. Ultimately, this project is intended to help improve online safety by offering intelligent, automated content moderation.

PURPOSE

Hate Speech Detection: To find and identify hate speech within meme content. Recognizing harmful messages hidden under the veil of humor is important to mitigate the spread of toxic content online.

Multimodal Learning: To analyze text and images together at the same time. Memes have both visual and text; multimodal learning allows the model to see the complete meaning of the meme being evaluated.

CLIP Model Utilization: Taking advantage of the Contrastive Language-Image Pre-Training model. The CLIP model transfers relevant features from text and image together into a shared space, allowing the model to know more about the context and understand what the words mean and relate to them.

Prompt Engineering: To clarify what should happen when we input the model. Well-designed prompt construction directs the CLIP model when interpreting the task at hand and enhances the performance for hateful meme detection.

Content Moderation: To help automate moderation in online environments. Accurately classifying hateful memes will mitigate the spread of these types of content online, filtering and flagging toxic materials before they permeate environments.

Online Safety: To make online spaces safer. Detecting hate speech contributes to a safer environment for online communities, and avoiding being a means of cyberbullying or radicalization.

Real-world Application: To build a system that could be used in the real world; since the model had an exceptional accuracies, we believe it has the potential to be embedded into social media moderation systems.

Advancing Deep Learning Research: To contribute to the knowledge and practice of AI. In this investigation we will push the boundaries of multimodal AI and offer some insights and methods which may be applicable in wider areas.

LITERATURE SURVEY

The field of hate speech identification has seen a lot of effort, but relatively little of it has focused on multimodal hate speech detection. Both NLP and network science have studied hate speech in depth. Hate speech has long been detected using language analysis. One of the key places where hate speech is targeted with a range of targets is social media. Obtaining a sentence embedding and putting it into a binary classifier for hate speech prediction are the typical processes for hate speech detection. A variety of language-based hate speech identification datasets have been made available for research on hate speech detection. According to Yang et al. adding image embedding information to text improves hate speech recognition ability right away. With the aid of Crowdflower employees, Hosseinmardi et al. categorize a dataset of Instagram photographs and the comments that go with them. After being tweaked and coupled with a random forest (RF) classifier, our model (OSCAR+RF) outperformed the other eleven (11) published baselines on the task of identifying nasty memes, reaching average accuracy and AUROC

of 0.684 and 0.768, respectively, in a public test set. In conclusion, our study has demonstrated that VL-PTMs with anchor point additions can improve the efficiency of deep learning-based hate meme identification by including a more robust deep learning model [7]. The study by Yi Zhou1, Zhenhao Chen2, and Huiyuan Yang on MULTIMODAL LEARNING FOR HATEFUL MEMES identification focuses on the identification of hate speech using a model based on Visual Question Answering [8]. The research on ‘‘The Hateful Memes Challenge: Detecting Hate Speech in Multimodal Memes’’ by Douwe Kiela, HamedFirooz, Aravind Mohan, VedanujGoswami, Amanpreet Singh, Pratik Ringshia, and DavideTestuggine suggests a new challenge set for multimodal classification that focuses on spotting offensive language in multimodal memes [9]. Problematic instances are included in the dataset to make it harder to rely on unimodal models and to demonstrate the superiority of multimodal models signals. Despite requiring complex reasoning, the task can be quickly reduced to a binary classification problem.

EXISTING SYSTEM

In the past hate speech detection systems made use of unimodal approaches that were focused only on textual analysis via blocklists, keywords matching or filtering methods. These unimodal approaches may have performed adequately for detecting explicit textual content, but these methods are incapable of understanding the contextual and nuanced meanings found in multimodal content like memes, in which images, text and the pairing of the two (in short, image-context) are used together with the intention of conveying a harmful message. Unimodal detection systems fail at model-training image-text alignment, and therefore cannot classify meme content correctly, which exposes the need advanced multimodal models like CLIP for the purpose of detection.

METHODS

1. SOCIAL NETWORK CREATION

- Social network refers to interaction among people in which they create, share, and/or exchange information and ideas in virtual communities and networks.
- Design the GUI which is the type of user interface that allows users to interact with users through graphical icons and visual indicators
- User can be sign in and sign up to the application.

2. MEMES IMAGES UPLOAD

- Memes are cultural symbols or ideas that spread virally across the internet.
- They can take many forms, including images, phrases, and even behaviors.
- Memes often convey humor, irony, satire, or commentary on various aspects of society. They spread rapidly through social media platforms, forums, and other online communities.
- In this module, user upload the memes images and forward to admin page for classification

3. TEXT EXTRACTION

- Extracting text from images, a process known as Optical Character Recognition (OCR), allows for the conversion of text contained within images into editable and searchable text format.
- Optical character recognition (OCR) is sometimes referred to as text recognition.
- OCR software singles out letters on the image, puts them into words and then puts the words into sentences, thus enabling access to and editing of the original content. It also eliminates the need for manual data entry.

4. TEXT CLASSIFICATION

- In this module, we can implement Text mining algorithm to extract the keywords from memes text
- Using Natural language processing algorithm, to perform stop words removal, stemming words analysis
- Then classify the text using VADER algorithm.
- Based on VADER algorithm, calculate the score values for text.

5. ALERT SYSTEM

- If the label is negative means, consider as offensive.
- And provide the warning at very first time upload offensive memes image.
- If the user again upload offensive image means, block the images.
- Finally user upload image more than 2 times means, automatically block the users from social network.

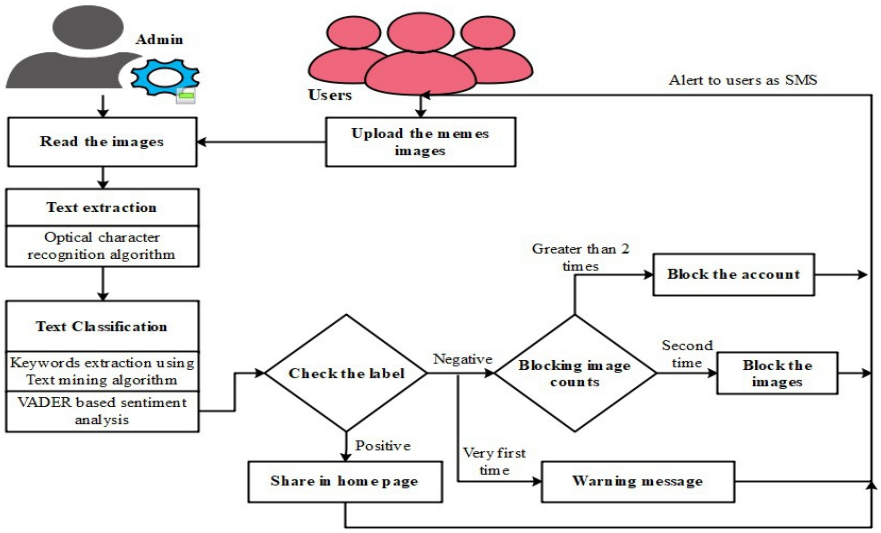
PROPOSED SYSTEM

The multimodal model represents a new system for hate speech detection in memes that benefits from Contrastive Language-Image Pre-Training (CLIP) with prompt engineering. This is unique in that the previous systems in hate speech detection were solely from the text-based standpoint while this provides simultaneous analysis of text and images for memes while being aware of the processing challenges inherent in modality with memes; while retrieving to text embedded in the image using Optical Character Recognition (OCR) and concurrently gauging the latent visual features respectively. All unique features go through the CLIP model for semantic alignment; the addition and use of prompt engineering represent a method of allowing the model to account for the semantic and functionality of the task through further instructions that would substantiate the model's understanding. This multimodal model had the ability to analysis hate speech in memes with higher accuracy and better contextual wholeness; showing the multimodal model was accurate with a classification accuracy rate of 87.42 percent. This system is meant to develop and test a model based on applicability and those researchers and people alike can use to support moderation systems and online safety and integrity on platforms that rely on digital interfaces, thus providing a scalable and efficacious model.

KEY COMPONENTS OF THE PROPOSED SYSTEM

- **Optical Character Recognition (OCR):** Extracts text embedded within meme images, converting visual text into machine-readable format for analysis.
- **CLIP Model (Contrastive Language-Image Pre-Training):** Aligns image and text in a shared semantic space, enabling understanding of the relationship between meme visuals and captions.
- **Prompt Engineering:** Customizes model input prompts to improve performance by guiding the model's interpretation of hate-related content.
- **Multimodal Feature Extraction:** Processes and combines both visual and textual features to understand the complete context of a meme.
- **Hate Speech Classification Module:** Classifies content as hateful or non-hateful based on the integrated analysis of text and image.
- **Evaluation & Accuracy Metrics:** Assesses the model's performance using accuracy (87.42%) and other metrics to ensure reliability and effectiveness.

SYSTEM ARCHITECTURE



FUTURE ENHANCEMENTS

- Expand language support to detect hate speech in memes containing non-English or multilingual content.
- Improve OCR accuracy for complex or stylized meme fonts using advanced vision models.
- Include user feedback mechanisms to continuously refine and retrain the model with real-world data.
- Enhance detection capabilities for sarcasm, coded language, and cultural references using contextual NLP models.
- Explore integration with other multimodal models like BLIP or Flamingo for even richer semantic understanding.

CONCLUSION

This project utilizes Contrastive Language-Image Pre-Training (CLIP) with prompt engineering and optical character recognition (OCR) to develop an effective and novel meme hate speech detection model. The proposed system represents a comparative advancement to current unimodal systems, which exclusively encode text for processing and analysis. The proposed model can successfully exploit a multimodal approach to capture the complicated semantic relationship between text and image and maintain a competitive classification accuracy. Moreover, the use of multimodal learning processes as mentioned above not only improves the accuracy of hate speech detection, but also offers flexibility for scalability for real-time deployment on social media platforms and large-scale content moderation for user safety. The adaptability of the system and the proposed projects and scale of model training makes it an appealing decision support tool for platforms managing the escalation of online hate speech. Future directions for the model or project could include employing a multilingual lexical basis, developing a sarcasm detection tool, and real-time deployment for social media platforms.

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Chapter 43

OTOSCOPIC IMAGE CLASSIFICATION USING DEEP LEARNING ALGORITHM

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ABSTRACT

Otoscopy plays a critical role in the assessment to fear health and the diagnosis of various ar-related conditions, particularly ear infections such as otitis media and otitis external .It is a fundamental diagnostic tool used during ear and hearing evaluations. Otoscopic examinations are commonly performed by a wide range of healthcare professionals including medical students, nurses, general practitioners, emergency medicine physicians, pediatricians, audiologists, and otolaryngologists. Despite its widespread use, the accuracy of otoscopic diagnosis is highly dependent on the clinician's level of training and experience. Misinterpretation of otoscopic findings can lead to incorrect diagnoses and inappropriate treatments, which can adversely affect patient outcomes. This project aims to develop a robust and intelligent framework for the classification of ear images obtained through otoscopy. By leveraging advanced image processing techniques and machine learning algorithms, the proposed system seeks to enhance the accuracy and consistency of ear disease diagnoses. The framework will be trained to recognize and classify a variety of common ear conditions from otoscopic images, thereby assisting healthcare professionals in making more informed decisions.

KEYWORDS

Otoscopic Image Classification, Deep Learning, Ear Disease Diagnosis, Medical Image Processing, Machine Learning

INTRODUCTION

The human ear is a vital organ responsible for hearing and maintaining balance. Any disruption in its structure or function can lead to significant health issues, including hearing loss, pain, and infections. Among the various methods used to assess ear health, otoscopy remains the most fundamental and widely adopted clinical procedure. It involves the visual inspection of the ear canal and tympanic membrane (eardrum) using an instrument called an otoscope. Otoscopy is an essential skill in routine physical examinations, particularly for diagnosing common conditions such as otitis media, otitis externa,

tympanic membrane perforations, and impacted cerumen.

Otoscopy is routinely performed by a broad spectrum of healthcare professionals, including medical students, nurses, general practitioners (GPs), emergency physicians, pediatricians, audiologists, and otolaryngologists (ENT specialists). Despite its ubiquity, the accuracy and reliability of otoscopic diagnoses vary significantly across practitioners, often depending on their level of training and clinical experience. Studies have shown that even trained medical personnel may misinterpret otoscopic findings, leading to under- or over-diagnosis, unnecessary treatments, or missed infections. This variability highlights a critical gap in clinical practice, especially in resource-constrained or primary care settings where specialists may not be readily available.

With recent advancements in machine learning (ML) and computer vision, there is growing interest in applying these technologies to healthcare diagnostics. In particular, automated image classification has shown promising results in fields such as dermatology, radiology, and ophthalmology. These technologies can be effectively adapted to otoscopy to develop intelligent systems capable of classifying ear conditions based on image data. By training models on a large dataset of annotated otoscopic images, it is possible to create a diagnostic tool that mimics expert-level accuracy and offers real-time assistance to healthcare providers.

The primary goal of this project is to develop a comprehensive framework for the classification of ear diseases using otoscopic images. This system will use deep learning and image analysis techniques to recognize and categorize ear conditions, thereby supporting clinical decision-making and improving diagnostic accuracy. Key components of the project include dataset collection and pre processing, model architecture design, training and validation of classification algorithms, and performance evaluation against expert-labeled ground truth data.

PURPOSE

The primary purpose of this study is to design and develop an intelligent framework capable of accurately classifying ear diseases using otoscopic images. This work is driven by the increasing need for consistent and reliable interpretation of otoscopic findings, particularly in settings where experienced clinicians may not be available. The traditional reliance on visual inspection by human examiners often leads to subjective diagnoses, which can result in missed conditions, misdiagnosis, or overtreatment. This variability poses a significant challenge in ensuring high-quality and uniform care, especially for common yet potentially serious ear conditions. The proposed system aims to reduce diagnostic discrepancies by leveraging machine learning, particularly deep learning models, to automate the classification of various ear pathologies. By doing so, it seeks to assist healthcare providers—especially those with less experience—in making accurate and timely decisions regarding ear health and treatment.

- **Improve Diagnostic Accuracy:** Enhance the reliability of otoscopic diagnoses through automated image classification, thereby minimizing human error and subjectivity.
- **Support Healthcare Providers:** Serve as a decision-support tool for clinicians, including general practitioners, nurses, and medical students, enabling them to identify ear conditions with greater confidence and accuracy.
- **Enable Early Detection:** Facilitate early and accurate detection of ear infections and other pathologies, which is essential for preventing complications and ensuring timely intervention.
- **Promote Consistent Care:** Standardize the interpretation of otoscopic images across different healthcare settings, ensuring patients receive consistent care regardless of the examiner's experience level.
- **Leverage Artificial Intelligence:** Utilize cutting-edge machine learning and computer vision techniques to build a robust and scalable classification model that can be integrated into telemedicine platforms, mobile health apps, or clinical decision systems.
- **Bridge Resource Gaps:** Address the shortage of specialized care in remote and underserved areas by providing a tool that can function as a virtual expert, assisting non-specialist healthcare workers in diagnosing ear conditions.

OBJECTIVES

- Gather a comprehensive set of high-quality otoscopic images representing both healthy ears and common ear diseases such as otitis media, otitis externa, tympanic membrane perforations, cerumen impaction, and others.
- Ensure the data set includes a wide demographic representation to support generalizable model training.
- Apply standard image preprocessing techniques such as resizing, normalization, and augmentation to enhance the model’s ability to generalize.
- Label each image accurately with diagnostic information validated by clinical experts to create a reliable ground truth for supervised learning.
- Develop a Convolutional neural network (CNN) or other suitable architecture capable of learning complex visual features from otoscopic images.
- Optimize the model's structure for accuracy, speed, and efficiency in medical environments.
- Split the data set into training, validation, and testing subsets to evaluate the model's performance.

EXISTINGSYSTEM

Otoscopyis one of the most common and essential clinical procedures for evaluating ear health. Traditionally, it involves the use of a handheld otoscope by healthcare professionals to visually inspect

the ear canal and tympanic membrane. While it is considered a standard and non-invasive diagnostic tool, the interpretation of otoscopic images remains highly subjective and experience-dependent. This has led to significant variability in diagnostic accuracy, especially among non-specialist practitioners such as general physicians, nurses, or medical students. Numerous studies have revealed that the diagnostic accuracy of otoscopic examinations can be as low as 50% among general practitioners, compared to much higher accuracy rates among experienced otolaryngologists. This discrepancy often results in overdiagnosis, under diagnosis, or inappropriate treatment—issues that can have serious consequences, particularly in pediatric populations where ear infections are more prevalent. To address these limitations, some initiative shave emerged in recent years to incorporate digital otoscopy and tele-otoscopy..Tele medicine platforms have made it easier to access expert opinions in remote areas; however, these systems still rely heavily on human interpretation and availability of specialists. More recently, the application of machine learning (ML)and deep learning (DL)has begun to show promise in automating diagnostic tasks across various fields of medicine, including dermatology, ophthalmology, and radiology. In the field of otoscopy, researchers have started to explore the use of Convolutional Neural Networks (CNNs) for classifying otoscopic images.

For example:

AI models like ResNet, VGG, and Efficient Net have been used in pilot studies to identify conditions such as otitis media, tympanic membrane perforations, and cerumen impaction. Some studies have reported classification accuracies of up to 85–90%, but often with limited datasets, which raises concerns about generalizability and real-world clinical application. A few mobile applications and prototypes have been developed for research purposes, but most are not widely deployed or clinically validated for broad use.

PROPOSED SYSTEM

The primary purpose of this study is to develop an intelligent, accurate, and accessible system for the classification of ear diseases using otoscopic images. This initiative is driven by the need to improve diagnostic consistency, especially among healthcare professionals with varying levels of experience, and to reduce diagnostic errors associated with traditional, manually interpreted otoscopy. While otoscopy is a standard and widely used diagnostic procedure, its effectiveness heavily depends on the skill and experience of the examiner. As a result, there is significant variability in the ability to correctly identify ear conditions such as otitis media, otitis externa, tympanic membrane perforation,and others. Misdiagnosis or delayed diagnosis can lead to complications such as hearing loss, chronic infections, or unnecessary use of antibiotics.This study aims to harness the power of artificial intelligence—particularly deep learning and image classification techniques—to develop a model that can accurately classify

otoscopic images into various diagnostic categories. The broader goal is motto replace clinicians but to support and enhance their diagnostic abilities, especially in primary care, emergency settings, remote areas, and low-resource environments where access to ear specialists may be limited.

More specifically, the purpose of this project includes:

To enhance diagnostic accuracy and reliability Reduce subjectivity in interpreting otoscopic findings by providing automated, data-driven classification.

To support healthcare workers across all levels Assist general practitioners, nurses, and medical students in accurately identifying ear diseases, regardless of their experience.

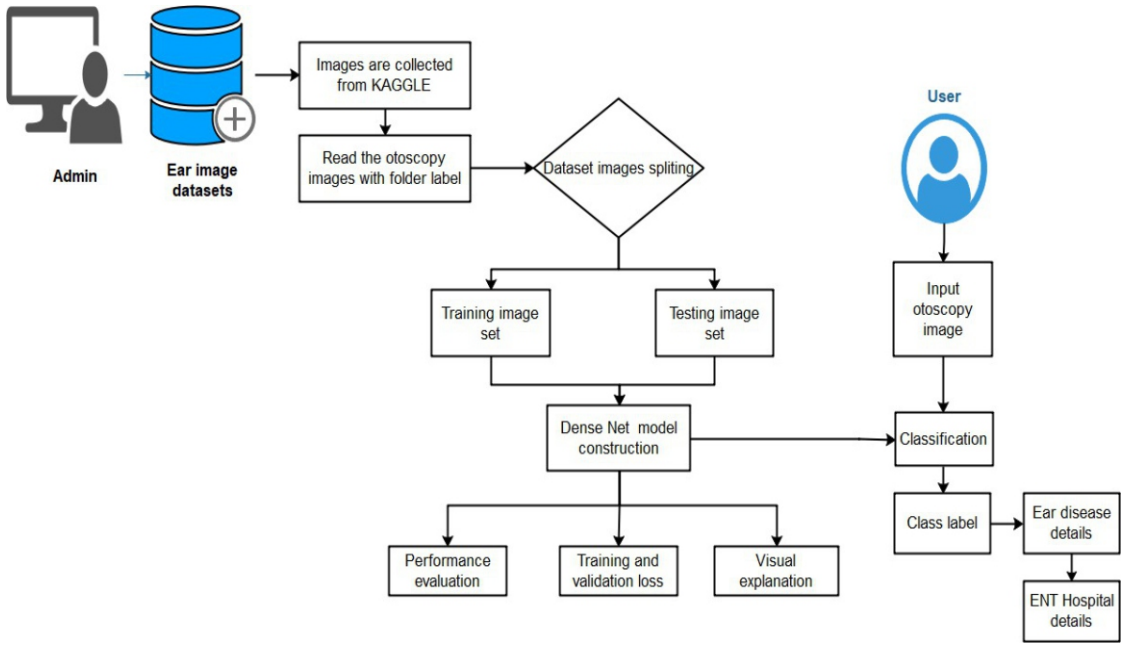
To improve early detection and intervention Enable prompt recognition of common and serious ear conditions to improve patient outcomes and prevent complications.

To develop a clinically applicable AI tool Design a practical and scalable system that can be integrated into real-world clinical workflows, telemedicine platforms, and mobile applications.

To bridge the expertise gap in underserved are as Provide reliable diagnostic support in regions lacking access to otolaryngologists or specialized equipment.

To contribute to medical training and education Offer a valuable learning resource for medical trainees by providing visual feedback and examples of various ear pathologies.

SYSTEM ARCHITECTURE



CONCLUSION

In conclusion, this study has demonstrated the effectiveness of utilizing Dense net Convolutional Neural Networks (CNN) for otoscopy classification. By leveraging the power of CNNs, we have achieved promising results in accurately categorizing ear images based on their pathological conditions. Our findings underscore the potential of CNN-based approaches in aiding medical professionals with rapid and reliable diagnosis of ear- related disorders. Moving forward, further research can explore enhancements to the CNN architecture, dataset augmentation techniques, and the integration of additional clinical data to improve classification performance.

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Chapter 44

Real-Time Suspicious Activity Detection in Surveillance Videos Using Deep Neural Networks

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ABSTRACT

Public safety remains one of the most pressing global challenges, particularly in environments such as workplaces, schools, airports, transportation hubs, and large public gatherings where violent incidents and the use of weapons can result in severe consequences. Traditional surveillance methods, though widely deployed, face critical limitations due to the overwhelming volume of video data that requires constant human monitoring, often leading to delayed responses and overlooked threats. To address these shortcomings, this study proposes an intelligent and fully automated deep learning–based weapon and violence detection system, integrating three powerful neural architectures: YOLO (You Only Look Once), VGG16, and ResNet-50. Through rigorous experimental analysis, YOLO emerges as the superior model, achieving 97.96% accuracy, significantly outperforming ResNet-50 (92.5%) and VGG16 (85.3%). Beyond static object detection, the framework incorporates temporal motion analysis, enabling it to differentiate between violent behaviors (such as sudden aggression) and normal actions (e.g., running or gesturing). Once a threat is detected, the system triggers real-time alerts to authorities with precise location and time, ensuring immediate intervention and minimizing escalation. The contributions of this work are threefold: (i) A comparative study of YOLO, ResNet-50, and VGG16 for real-time weapon detection; (ii) A scalable, high-performance architecture adaptable to diverse surveillance environments; (iii) An intelligent alerting mechanism that enhances response speed and reduces false positives. Results confirm YOLO as the most reliable framework for automated surveillance, offering a transformative leap in safety technology for smart cities and high-risk infrastructures.

KEYWORDS

Video Surveillance, Deep Learning, Real-Time Detection, YOLO, ResNet-50, VGG16.

INTRODUCTION

Violence and weapon-related crimes are increasing at an alarming rate, posing severe threats to both individuals and communities. Whether in crowded public areas, schools, or critical infrastructure facilities, the ability to detect weapons such as knives, firearms, or explosive materials in real time can mean the difference between prevention and tragedy. While surveillance cameras are widespread, their effectiveness is undermined by information overload—security personnel cannot realistically monitor multiple video streams continuously and respond without delay. Human fatigue, subjectivity, and distraction contribute to this challenge, underscoring the urgent need for automated, intelligent, and real-time surveillance systems. Among these advancements, YOLO has emerged as a state-of-the-art object detection framework, celebrated for its remarkable speed and accuracy. Unlike traditional detectors that generate region proposals and then classify them, YOLO reframes detection as a single regression problem, simultaneously predicting bounding boxes and class probabilities in a single evaluation. This makes YOLO exceptionally efficient for real-time applications, where milliseconds matter.

This study focuses on designing and evaluating an intelligent hazardous activity detection system that leverages YOLO, ResNet-50, and VGG16. By comparing these models, we establish YOLO as the most effective solution for detecting weapons in real-world surveillance footage. Furthermore, the system integrates motion pattern analysis to distinguish aggressive behavior from routine movements, enhancing its contextual awareness. The significance of this work lies not only in its technical accuracy but also in its practical applicability. The proposed system can be deployed in high-security zones (airports, government facilities), public transport networks, commercial hubs, and even smart city infrastructures, contributing to safer and more resilient societies.

Key Contributions of this Research:

1. Comparative Evaluation: Systematic comparison of YOLO, ResNet-50, and VGG16 for weapon detection in dynamic environments.
2. High-Performance Detection: YOLO achieves near-perfect accuracy (97.96%) with superior precision and recall, establishing its dominance in real-time scenarios.
3. Alert Mechanism: Real-time notification system minimizes human error and drastically reduces response time.
4. Scalable Framework: Designed for seamless integration with existing surveillance infrastructure across diverse environments.
5. Future-Ready Design: Potential for integration with smart city IoT networks, drones, and federated learning frameworks.

RELATED WORK

A vast body of literature highlights the role of deep learning in enhancing surveillance and violence detection. Dong et al. [1] proposed an intelligent face detection method using cascaded feature fusion, significantly improving recognition accuracy under dynamic lighting and occlusion. Zhang et al. [2] utilized Mask RCNN for vehicle damage detection, demonstrating how instance segmentation can capture intricate structural patterns. Similarly, Lin et al. [3] presented fall detection on neuromorphic processors, showing that surveillance models can be implemented on low-power, real-time hardware with high reliability. Human attribute recognition has been advanced through hybrid transformer networks [4], while vehicle re-identification frameworks [5] contribute to smart city monitoring. Privacy-aware approaches, such as federated learning for fall detection [6], highlight the increasing emphasis on safeguarding sensitive data in surveillance systems. Specifically, in violence detection, Ullah et al. [7] combined optical flow CNNs with LSTM-based temporal modeling to detect aggressive acts. Ye et al. [8] extended this concept by incorporating audio-visual fusion, recognizing campus violence more effectively. Li et al. [9] enhanced YOLO networks for detecting small-scale objects like knives and pistols, while Wu et al. [10] designed tracking algorithms that improved multi-object reliability in dynamic environments.

PROPOSED SYSTEM

The proposed system integrates YOLO-based detection with behavioral analysis for enhanced real-time monitoring. Its workflow can be divided into the following stages:

A. Data Collection

Surveillance cameras (RGB and thermal) capture video streams. Motion sensors and acoustic devices supplement the dataset with contextual cues.

B. Preprocessing

Video frames are normalized to reduce computational complexity. Background noise and irrelevant artifacts are filtered out. Acoustic data are transformed into spectrograms for better classification.

C. Object Detection

YOLO, ResNet-50, and VGG16 are deployed to detect weapons (guns, knives, etc.).

YOLO demonstrates the highest accuracy and real-time efficiency.



Figure 1. Sample dataset

D. Model Training and Fine-Tuning

Pre-trained models are fine-tuned using large annotated datasets of weapons and hazardous behaviors. Optimizers and dropout layers are employed to minimize overfitting.

E. Threat Recognition

Beyond object detection, motion analysis is applied to distinguish violent gestures (punching, stabbing) from harmless actions (running, waving).

F. Real-Time Alert Generation

Once a threat is detected, the system automatically sends alerts containing the time, location, and nature of the threat to relevant authorities. Notifications are delivered via SMS, mobile app, or integrated control-room dashboards.

G. System Architecture

The architecture combines YOLO's rapid object detection with contextual analysis to achieve low-latency, high-accuracy, and reliable decision-making, ensuring a practical balance between speed and precision.

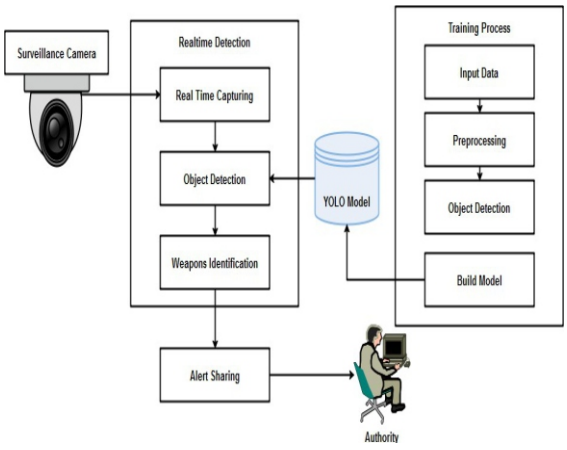


Figure2. Architecture diagram for suspicious activity detection

RESULT ANALYSIS

The system was evaluated using datasets containing thousands of annotated images of weapons and violent activities. Three models—YOLO, ResNet-50, and VGG16—were tested for performance across multiple metrics.

Performance Summary:

YOLO: 97.96% accuracy, 93.4% precision, 95.0% recall, F1-score 93.1%

ResNet-50: 92.5% accuracy, moderate recall but slower response.

VGG16: 85.3% accuracy, high computational cost, unsuitable for real-time use.

Interpretation:

YOLO's high recall ensures minimal missed detections, critical for security applications.

Its high precision reduces false positives, preventing unnecessary alarms. The superior F1-score indicates a balanced and robust performance. Real-time tests confirm YOLO's ability to process video streams at frame rates exceeding 30 FPS, making it deployment-ready.This demonstrates that YOLO is not only theoretically superior but also practically implementable in real-world scenarios.

CONCLUSION & FUTURE WORK

This research presents an advanced deep learning–based system for hazardous activity detection, confirming YOLO as the most effective model for real-time surveillance. By achieving superior accuracy, recall, and precision, YOLO outperforms ResNet-50 and VGG16, proving itself as a robust framework for weapon detection and violence monitoring.The system's ability to generate instant alerts transforms surveillance from passive observation into a proactive defense mechanism, enabling authorities to respond promptly and effectively. This innovation holds significant potential for deployment in airports, public transport systems, government facilities, and educational institutions, contributing to safer communities.

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Chapter 45
Activity Optimization on Grid computing virtual organization with their Geographical Distance

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ABSTRACT

Grid computing enlarge with computing platform that is a collection of heterogeneous computing assets related with the aid of a network across dynamic and geographically dispersed employer to form a dispensed high performance computing infrastructure. Process optimization with effective utilization of heterogeneous resource completed by using computational grid and service grid. In this paper we provide an explanation for carrier grid environment which distribute duties to executors around the sector where time play important function

KEYWORDS

Job optimization, provider grid, heterogeneous aid, geographical distance, virtual company.

INTRODUCTION

The Grid [1] is a unified computing platform which consists of heterogeneous sources(e.g. processors, statistics storages, catalogs, networks and sensors etc) over massive geographical areas that exhibit one of a kind availability patterns over the years because of administrative polices of different domain names. Computational Grids allow the sharing and aggregation of tens of millions of sources geographically dispersed across corporations and administrative domain names. They contain heterogeneous resources (desktops, work-stations,clusters, and supercomputers), cloth control systems (unmarried system photo OS, queuing systems, and many others.) and guidelines, and applications (medical, engineering, and commercial) with numerous necessities (CPU, I/O, memory, and/or community in depth) which are then shared among dynamic virtual agencies. provider grid pursuits to abstractly describe, organize and manipulate the dynamic mixture of offerings, to assist relevant virtual corporation in open environments and flexible powerful useful resource sharing and enterprise-degree cooperation in virtual companies [2] due to the fact the sources in grid environment are owned by means of different organizations with their own control rules, usage and cost models for unique customers priorities and fee models, resources management and process scheduling grow to be one of the primary demanding situations in studies place of grid. [3]while as compared with the job scheduling in computational grid, the assignment scheduling in carrier grid, that's specialized in utility carrier

integration and helps multi-company cooperation, has its special characteristic. In computational grid, there's no need or hardly ever want for humans to participate that is due to the fact the computational grid normally worries the computational problem and the computational tasks are performed with the aid of computer systems. In service grid environments, but, there can be many offerings which want the participation of people besides the ones supplied robotically by using computer systems. However, human beings cannot work without rests. Therefore, each corporation, in particular for authority's institutions, has setup a piece calendar machine to separate the working day and holiday as well as working time and off-paintings time in a operating day. It way some offerings will best be available intermittently. Fortunately, due to the distinction of time area, at a precise time factor, there are a few organizations are on-responsibility whilst others are off-work. Consequently, the time factors, inclusive of the distinction of time area and paintings calendar gadget can play an essential function for activity optimization scheduling in service grid. Based on the have a look at on time management model in workflow, this paper proposes a completion-time-based optimization version for activity scheduling in carrier grid environments.

LITERATURE SURVEY

Research in Grid computing and job scheduling has evolved over the last two decades, moving from basic computational models to sophisticated adaptive and economic frameworks.

Economic Models for Grid Scheduling

One of the pioneering contributions in this field was the Grid Architecture for Computational Economy (GRACE), which established a distributed computational economy framework flexible enough to accommodate multiple economic models [4]. These approaches introduced concepts such as cost, time, conservative-time, and cost-time optimization. Building on this framework, Nimrod-G was developed as a Grid resource broker that supports deadline- and budget-constrained scheduling for parameter-sweep applications.Such economic-based approaches provided a foundation for market-driven resource allocation, enabling users to trade off between performance and cost, a crucial step in making Grid systems sustainable for large-scale scientific and industrial applications.

Simulation Tools for Grid Research

To evaluate scheduling policies systematically, simulation environments such as GridSim were created. GridSim allows discrete-event–based simulations, providing researchers with a platform for repeatable and controlled experimentation [4]. Through this toolkit, scheduling algorithms could be tested under diverse scenarios of varying user demands, deadlines, budgets, and geographical distribution of resources.This contributed to the scalability and reproducibility of research in Grid computing, ensuring that findings could be generalized across multiple deployment environments.

Adaptive Scheduling and Prediction Models

Beyond static scheduling, researchers also introduced adaptive models. Gao et al. [5] proposed two prediction models for job completion time in service grids:

- A single-service model, designed for environments providing only one type of service.
- A multi-service model, suitable for more complex environments offering multiple services.

To minimize job completion times, genetic algorithms were applied at both system and application levels, ensuring optimal allocation of tasks. These adaptive strategies highlighted the importance of predictive intelligence in scheduling, where job allocation decisions are guided by forecasted execution times rather than static estimates.

Economics and Market-Oriented Scheduling

Buyya et al. [6] expanded the economic perspective by applying concepts from real-world markets to Grid resource management. Their work explored commodity market pricing, bargaining, contract-net models, and auction mechanisms. These strategies ensured fair allocation of distributed resources while respecting user-defined constraints such as time and cost.

Such economic models aligned Grid computing with service-oriented computing principles, where users and providers interact in a market-like ecosystem, negotiating based on supply and demand.

Middleware and Workflow-Oriented Models

Other systems, such as Legion, employed object-oriented middleware components for resource management, including schedulers and enactors. These middleware-based approaches enabled seamless integration of diverse resources and services, while workflow models introduced time-management concepts [3,7]. In particular, the workday model integrated human calendars into Grid scheduling, highlighting the need to account for non-computational factors such as organizational working hours.

METHODS

Economic-based Grid gadget advanced a disbursed computational economic system framework known as the Grid architecture for Computational economy (GRACE), that is accepted sufficient to house one of a kind financial models and maps nicely onto the architecture of wide-place dispensed structures, designed deadline and budget limited scheduling algorithms with 4 distinct techniques along with value, time, conservative-time, and price-time optimizations, developed a Grid resource broking called Nimrod-G that supports cut-off date and price range confined algorithms for scheduling parameter sweep packages on the Grid, evolved a Grid simulation toolkit, called GridSim, that helps discrete-occasion primarily based simulation of Grid environments to permit repeatable overall performance evaluation beneath one-of-a-kind eventualities, evaluated the performance of deadline and scheduling algorithms through a sequence of simulations through varying the range of users, deadlines, budgets, and

optimization techniques and simulating geographically distributed Grid resources, and tested the effectiveness and application of Grid technology for solving real-world issues which includes molecular modeling for drug design at the WWG (global-huge Grid) tested[4].[5]Adaptive carrier grid task scheduling proposes two models for predicting the completion time of jobs in a service Grid. The single carrier version predicts the final touch time of a task in a Grid that gives most effective one kind of carrier. The couple of services model predicts the of entirety time of a process that runs in a Grid which gives more than one forms of offerings. In this paper they presented models for predicting the of entirety time of jobs in a provider Grid. The single provider version predicts the final touch time of an activity in a Grid that gives best one form of carrier. The couple of services version predicts the of completion time of an activity that runs in a Grid which gives more than one forms of offerings. The 2 set of rules that use the expected outcomes to time table jobs at each machine degree and alertness stage. In software-degree scheduling, we use genetic algorithms to decrease the average finishing touch time of jobs via optimal job allocation on every node. Buyya et al. [6] proposed an economics model for Grid resource control and scheduling, using advertising ideas together with commodity marketplace, published price modeling, bargaining modeling, contract internet modeling, public sale modeling and others. Scheduling algorithms for time-optimization and cost optimization had been designed within the Nimrod device. The Legion gadget makes use of 3 object-oriented middleware components, Enactor, Scheduler and collection, for aid management.

PROPOSED SYSTEM

Fig. 1 shows a layered architecture of a service Grid [5] Logically, the architecture is divided into four levels: the Virtual Organization level, the Grid level, the Admin Domain level and the Node level. The Node level can be a computer, a service-provider and a storage resource. The Admin Domain level consists of machine groups, named as Admin Domains (AD), in which all nodes belong to one organization.

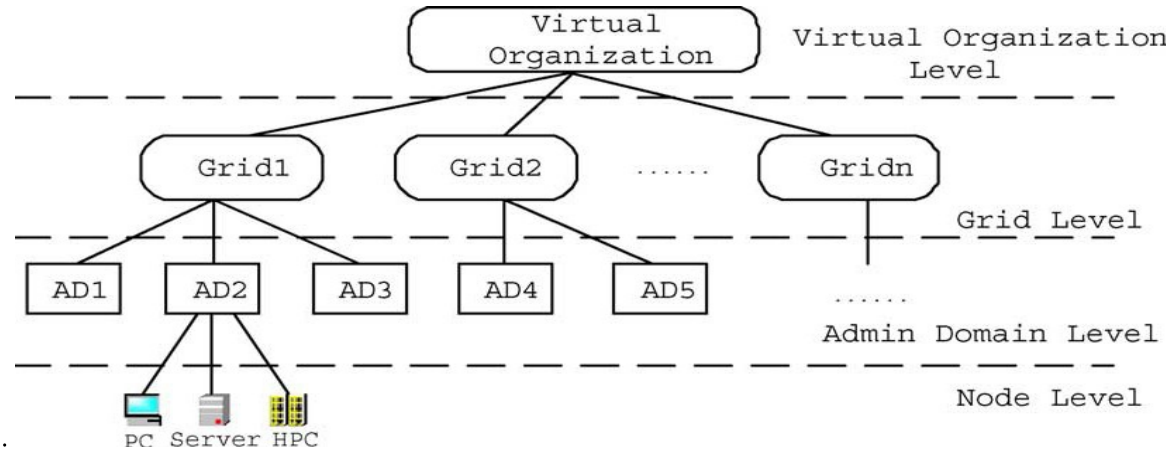


Fig. 1. The layered architecture of a service Grid

as an example in Fig.1, AD1 belongs to the laptop center and AD2 belongs to the department of pc technological know-how. On one hand every advert may be regarded as an entire gadget, and all nodes in it have a commonplace goal. on the other hand, an advert can fully centrally control the sources of its nodes but cannot function the sources of nodes in different ads directly.

on this view, all nodes are cooperative inside the equal advert. A Grid will have many commercials linked together and have precise collaboration and accept as true with relationship among the commercials. as an example, Grid1 in Fig. 1 can be a Grid in London and Grid2 is a Grid in California. However, Grids are unbiased to every different, users can put up tasks to a Grid from its Portal. The pinnacle virtual enterprise (VO) stage combines all Grids collectively.

Task flow model in a job and its Simplification:

The diversity and complexity of the mission waft in an activity makes us hard to discover a task scheduling process model. Thankfully, we can simplify diverse and complicated mission go with the flow styles in a process by way of assorting them. go with the flow sample can be divided into serial pattern and parallel pattern. The parallel sample can be in addition subdivided into two sorts: “AND-parallel” and “OR parallel”[4]. Every of them is shown in Fig. 2. Challenge T4, T8, and T10 represent an instance of serial sample whilst assignment T5, T6, and T7 constitute an instance of parallel pattern. to analyze the undertaking scheduling optimization, we introduce the idea of “block”. This is, we will encapsulate every sample into a “block” and represent it as an unmarried node in the go with the flow recursively till a purely serial pattern is received. The simplification is finished as follows. First of all within the parallel obligations T5， T6 and T7 are combined into a parallel pattern block B1, then in the parallel sample T5, T6 and T7 blended into a parallel block B1.subsequent serial duties T3, B1 and T9 are combined into a

serial pattern block B2. Combined into a serial pattern block B2. Then T4, T8 and T10 are combined into a serial pattern block B3. Then the parallel tasks B2 and B3 combined into the parallel pattern block B4. Finally a serial task scheduling flow is formed in Fig 2.

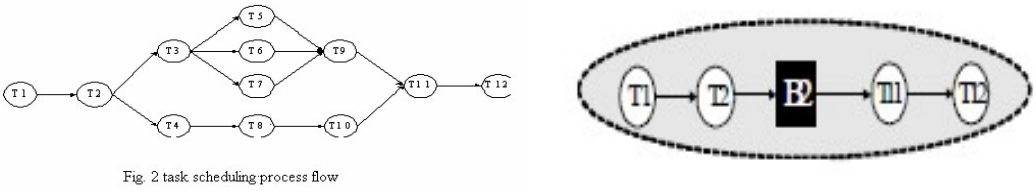


Figure 2. Serial task flow

Computation of task waiting time at a Station:

Think that a process includes a chain of Responsibilities, i.e., task= {Task1, Task2, Taskn}. And to better construct the process scheduling model and optimize it, we define some parameters as in table1. Supposing challenge I T arrives a station at ij tarr , the paintings time in this station may be computed via taking (t min1j) stands for the start time of work inside the morning and (t max1j) stands for its cease time; (t min2j) stands for the start time of work in the afternoon and (t max2j) stands for its stop time; (rest1j) stands for the relaxation time at midday and (rest2j) stands for the relaxation time at night. Then we will get the ready time of undertaking Ti at this station, WTij as components (1):

$$WTij = (24- Dj)* ET ij / Dj + rest1j * f(x1)+ rest2j *f(x2)$$

A case take a look at :[7]suppose there are five stations for processing responsibilities, i.e., s1, s2,s3, s4 and s5. Station, s1, is at London, which uses Greenwich Mean Time. Station, s2, is at California of the United States, which uses Pacific Standard Time and its far 8 hours at the back of of GMT. Station, s3, is at New York of america, eastern popular Time and 5 hours at the back of of GMT. Station, s4, is at Beijing of China, 8 hours in advance of GMT. Station, s5, is at Moscow of Russia and 3 hours in advance of GMT. We also assume that the execution time of each undertaking at one station is as proven in table2 and those five stations all work 5 days every week. But station s1 and s3 work seven hours a day, from 9o'c lock to twelve o'clock inside the morning and 13 to 17 inside the afternoon. The alternative 3 stations work 8 hours a day, in which station s2 and s4 work from eight to 12 in the morning and 14 to18 in the afternoon while station s5 is from 8 to twelve inside the morning and thirteen to 17 inside the afternoon. The begin time of the go with the flow is 10'clock of GMT. According to above evaluation, we are able to get: start time of the float is 10'clock of GMT. consistent with above evaluation, we can get: The best execution time is five hours and the corresponding stations which execute the responsibilities T1, T2, T3, T4 are s2, s1, s5, s5. If we do not make use of the time distinction and execute the duties

within the process at only one station, the full execution time may be greater than 9 hours for all stations. Hence, we are able to see the most suitable scheduling model could be very beneficial and sensible.

Parameters	Description
Total time - T_{total}	Denoted total execution time of the job
Executed time - ET_{ij}	Denotes execution time of task i at the station j
Wait time - WT_{ij}	Denotes waiting time of task i at the station j
Arrive time - $tarr_{ij}$	Denotes time of task i arrived at the station j
Station work time - D_j	Working time of station j at working day
Zone difference - H_j	Denotes the time zone difference between station j and the scheduling station. It may be positive or negative.

Table 1. Parameter to compute wait time of a job

Station / Task	S1	S2	S3	S4	S5
T1	2	1	2	3	4
T2	1	3	2	3	5
T3	4	2	2	1	1
T4	5	3	4	4	2

Table 2. The required execution time of tasks at each station

Ts = 10;

H_1=0; H_2=8; H_3=5; H_4=-8; H_5=-3;

t min_{11} =9; t max_{11}=12; t min_{21}=13;

t max_{21}=17;

t min_{12} =8; t max_{12}=12; t min_{22}=14;

$t\ max_{22}=18;$

$t\ min_{13}=9;\ t\ max_{13}=12;\ t\ min_{23}=13;$

$t\ max_{23}=17;$

$t\ min_{14}=8;\ t\ max_{14}=12;\ t\ min_{24}=14;$

$t\ max_{24}=18;$

$t\ min_{15}=8;\ t\ max_{15}=12;\ t\ min_{25}=13;$

$t\ max_{25}=17;$

$ET_{11}=2;\ ET_{12}=1;\ ET_{13}=2\ ;\ ET_{14}=3;$

$ET_{15}=4\ ;$

$ET_{21}=1;\ ET_{22}=3;\ ET_{23}=2\ ;\ ET_{24}=3;$

$ET_{25}=5\ ;ET_{31}=4;\ ET_{32}=2;\ ET_{33}=2\ ;\ ET_{34}=1;$

$ET_{35}=1\ ;ET_{41}=5;\ ET_{42}=3;\ ET_{43}=4\ ;\ ET_{44}=4;$

$ET_{45}=2\ ;$

RESULTS AND DISCUSSION

To evaluate the effectiveness of the proposed time-difference–aware scheduling model, a case study was conducted across five geographically distributed stations**:**

- **S1 – London (GMT)**
- **S2 – California, USA (PST, GMT–8)**
- **S3 – New York, USA (EST, GMT–5)**
- **S4 – Beijing, China (GMT+8)**
- **S5 – Moscow, Russia (GMT+3)**

Each station followed its own working calendar and hours. For example, S1 and S3 operated for seven hours daily (split between morning and afternoon sessions), whereas S2, S4, and S5 operated for eight hours daily. Tasks had to be executed only during the active working hours of each station, simulating a service grid where human involvement and organizational rules are crucial**.**

A set of four tasks (T1–T4) were scheduled across these stations, with execution times varying at each location (see Table 2 in the original paper). The scheduling model considered both execution time and waiting time based on time zones and working calendars.

CASE STUDY RESULTS

- **Without optimization** (assigning all tasks to a single station):
    - Total completion time exceeded **9 hours**, regardless of which station was chosen.
    - This is due to idle waiting time during off-work hours and limited station capacity.

- **With the proposed optimized scheduling model** (leveraging time zones and work calendars):
    - Tasks were distributed intelligently across stations (e.g., T1 at S2, T2 at S1, T3 & T4 at S5).
    - The total completion time was reduced to **5 hours**.
- This clearly demonstrates the **efficiency gain of nearly 45%** compared to non-optimized scheduling.

CONCLUSION

Evince grid can offer us some surroundings to distribute tasks to executors around the world. Considering the fact that there exist distinction of time area and running calendar device for independent organizations, there may be some groups are on-duty at the same time as others are off work at a targeted time factor. Aiming at utilizing the time distinction, this paper proposed and built a mathematical version to solve the problem finishing touch time optimization of challenge scheduling in those environments. A case examine is analyzed and it's miles shown that the entire execution time of the project may be shortened very an awful lot whilst compared with the normal state of affairs. We will apply the greedy algorithm to compute the most excellent execution time. In our experiment, we use Mat Lab 7.0 because the programming device.

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Chapter 46
AUTOMATIC INFORMATION EXTRACTION FROM SEMI-STRUCTURED SOURCES

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ABSTRACT

Semi-structured information embedded in HTML and similar document formats represents a rich source of valuable data that can be leveraged for automatic information extraction. Unlike fully structured databases, these documents often contain loosely organized content such as single data items, simple lists, or more complex hierarchical lists. Effective extraction systems must therefore integrate techniques from both information retrieval and pattern recognition to accurately identify and capture these varying data structures. By utilizing retrieval methods alongside extraction algorithms, systems can isolate relevant information with greater precision, enabling applications such as product comparison, event aggregation, or content summarization. A key innovation in recent approaches is the adoption of user-driven methodologies that significantly reduce the dependency on expert knowledge for designing extraction rules or models. This democratization of information extraction empowers ordinary users to interact with the system intuitively, guiding it through examples or minimal input, thereby making the technology more accessible and flexible in handling diverse data sources. One of the primary challenges in extracting information from semi-structured web data is managing lists with heterogeneous or irregular structures. Unlike simple tables or uniform lists, many web pages present data in nested or inconsistent formats, which complicates the identification of patterns necessary for reliable extraction. To address this, agent-oriented systems have been proposed that allow non-expert users to train extraction models interactively and with minimal effort. These systems use adaptive learning mechanisms and feedback loops to improve extraction accuracy over time, even when confronted with varied site designs and content layouts. Experimental evaluations demonstrate that such systems can effectively extract data across different websites, showcasing robustness and adaptability in real-world scenarios. However, despite these promising results, ongoing research is required to extend these capabilities to more advanced tasks, such as dealing with dynamic content, handling ambiguity in data semantics, and scaling extraction to large and rapidly changing datasets.

KEYWORDS

Automatic Information Extraction, Semi-Structured Data, Web Data Mining, Pattern Recognition, Adaptive Learning Systems

INTRODUCTION

Information extraction (IE) is the process of identifying relevant subsets of textual information and organizing them into structured data, unlike text understanding which captures full document meaning. Applications include shopping agents comparing products, event agents collecting schedules, and news agents filtering articles. IE is essential since natural text and semi-structured data (e.g., HTML) are too complex to process directly. Unlike information retrieval (IR), which returns documents, IE provides specific answers but is usually domain-dependent. Semi-structured text lies between unstructured natural language and structured databases, making it suitable for extraction without heavy NLP. Wrappers are IE components that convert semi-structured input into structured output, often built automatically through machine learning. Their effectiveness is measured by coverage and adaptability rather than precision/recall. This paper focuses on semi-structured list extraction, such as product catalogs, event calendars, or ads. Since general IE across all domains is difficult, a user-driven IE system is proposed, allowing non-experts to easily adapt extraction to new domains without programming skills.

LITERATURE REVIEW

The field of information extraction (IE) has evolved through multidisciplinary efforts aimed at efficiently extracting structured information from diverse sources. Guarino (1997) highlights the importance of formal ontological distinctions in semantic matching, which underpin the organization, extraction, and integration of information, emphasizing a knowledge-based approach to IE that improves precision through formal semantics [1]. Cunningham (1999) provides a comprehensive overview of IE systems, outlining practical methodologies and challenges in extracting meaningful data, particularly emphasizing the need for user-centered system design to enhance extraction usability and adaptability [2]. Early foundational work by Cowie and Lehnert (1996) explores IE as a key technology for transforming unstructured text into structured representations, identifying core components such as named entity recognition and template filling that continue to influence the field [3]. Soderland (1997) advances the domain by proposing machine learning techniques, particularly wrapper induction, to automate extraction from semi-structured web data, reducing reliance on manually crafted rules and enabling scalable information retrieval from the internet [4]. Building on this, Kushmerick (2000) rigorously analyzes wrapper induction methods, focusing on their efficiency and expressiveness, and addresses challenges related to the robustness and generalization of extraction patterns in noisy web environments [5]. Collectively, these works lay the groundwork for modern IE systems that combine formal semantic

frameworks with machine learning approaches to effectively extract information from semi-structured and unstructured sources.

PROPOSED SYSTEM

The ISSIE System

The ISSIE (Intelligent Semi-Structured Information Extraction) system is a user-driven tool for extracting data from semi-structured lists. It requires no expert skills, ontologies, or complex rules. Instead, it monitors a user's browsing behavior: during a training phase, the user navigates to pages and marks examples of data (singleton, list, or complex list). The system then enters the examination phase, repeating the navigation and identifying the data automatically. If successful, it proceeds to the extraction phase, where it can continuously retrieve updated information (e.g., product lists, events, news). ISSIE uses a proxy server to capture technical details like cookies, forms, and browser dependencies, enabling reliable extraction. Its architecture consists of an agent system for analysis and automation, and a user interface for training and management

The Agent Sub-System

The automated extraction process is built on the JADE platform using an agent-oriented approach for easier design and abstraction. The system includes Surfer agents that download and parse web pages, Analyzer agents that identify relevant information, and a Butler agent that manages communication with users. Agents communicate through an ontology created in Protégé and integrated with JADE and the Jess reasoning engine. When a new task is trained, the Butler triggers the Analyzer, which uses data from the Surfer's parse trees to examine and extract information. The Analyzer operates on abstract models rather than raw HTML, making it adaptable to non-HTML documents with semi-structured data. Surfer agents handle HTTP requests, responses, and parse trees, while the Analyzer applies knowledge-base rules to complete the extraction.

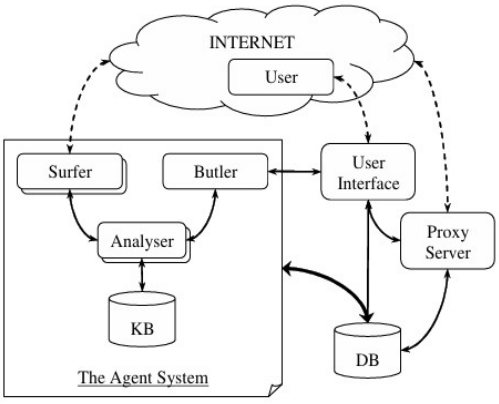


Figure 1. ISSIE Architecture

The Semi-Structured Document Model

ISSIE mainly relies on semi-structured information, unlike other systems that use linguistic or semantic techniques such as named entity recognition or WordNet. While these could improve ISSIE, they are less suitable for semi-structured text, which often contains fragmented sentences. In many cases, semi-structured information alone is sufficient for extraction. To use it effectively, documents are transformed into parse trees, where nodes represent block elements and links represent parent–child relationships. ISSIE focuses on block-level elements since they usually separate text pieces, though inline and linguistic data could be added in the future.

The Sibling Algorithm

The semi-structured information is used both for navigating through the document, locating the relevant, and to find all the siblings in a list. When a user adds a (simple) list during the training phase, he/she is supposed to provide the content for two pieces in the list. Using only the information about the content and the semi-structured information in the document, the system shall be able to locate all remaining siblings in the list. The algorithm basically searches for the smallest possible paths to the siblings and store that path for each given sibling. These paths are then used to find all remaining sib lings in the lists.

The Examination Process

After training, the system enters the examination phase to repeat the extraction. The Butler agent triggers the Analyzer, which follows these steps:

(1) The Surfer agent parses requests and builds parse trees;

(2) Extraction nodes and their siblings are marked;

(3) The Analyzer applies heuristic rules with three plans. Plan 1 requests only pages with extraction points; if that fails, Plan 2 requests pages with form submissions (e.g., logins or searches); if that also fails, Plan 3 requests all training session pages in order. Once a plan succeeds, it is stored for future use; otherwise, the system notifies the user of failure.

The User Interface

The user interface to the ISSIE system allows the user to manage the extraction tasks. The user can train the system to handle new tasks and modify existing tasks. The interface is a traditional web interface built using .Net. It is necessary for the interface to be simple enough so that users are not required to be computer experts. Due to the space limitations of the paper, it is not possible to include any detailed information about the interface. However, since it is a traditional web interface, there is not much relevance to give any detailed information. A small screen shot is given for the page that manages a

Table 1. List of experiments

Top news stories	Extract headlines of the current top news stories and the current top story from http://www.cnn.com/
Current scientific	Extract current scientific news stories headlines from http://news.google.com/
Video drivers	Extract video driver updates for a specific computer model from http://www.dell.com/

task in figure 2. From that page, it is possible for the user to give basic information about the task, to train the system, and modify other information for the task.

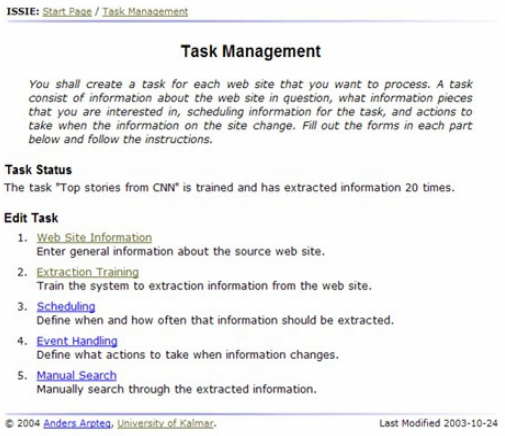


Figure 2. User Interface: Task Management

3. Experiments To evaluate the semi-structured list extraction hypothesis, a set of experiments was conducted using the ISSIE system. These experiments consist of extraction tasks such as extract the available driver updates for a particular computer model from a manufacturer's homepage. The list of experiments conducted is shown in table

The chosen extraction tasks are relevant and applicable across different websites. Each experiment follows these steps: (1) the user creates a task in ISSIE with a name and start URL, (2) configures proxy settings, then navigates to pages with desired information, (3) provides examples by copying single items or two list elements into the ISSIE interface, and (4) ends training by clicking "training complete." The ISSIE agents then analyze and attempt to repeat the process. If successful, automated extraction begins; otherwise, the user may need to add more examples and re-train.

RESULTS

The system was able to find the given extraction pieces and most of the times find the additional items in lists. There were some problems to correctly find all items in a list for some tasks, since the structure for list item was not always identical. Here is some more detailed information about each experiment:

CONCLUSION

This paper hypothesizes that a user-driven approach to semi-structured complex list extraction can enable many extractable domains. Applications range from simple change notifications to supporting the Semantic Web by transforming HTML into semantic formats like RDF or OWL. The improved ISSIE system now handles complex lists with varied structures, though challenges remain with multi-page tables. Future work will extend support for such lists by letting users demonstrate navigation between pages. Experiments show that using a proxy to capture technical details makes the system effective, even for advanced sites. The system allows non-experts to create extraction tasks easily, producing XML output that can be enriched with semantic knowledge for broader use.

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Chapter 47
AI-ENABLED ROAD ACCIDENT DETECTION AND RESCUE MANAGEMENT

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ABSTRACT

AI-enabled real-time road accident detection and rescue management system that integrates IoT devices, cloud computing, and artificial intelligence techniques. The system employs multiple sensors, including temperature, gas, and vibration sensors, to detect accidents and assess vehicle conditions. It consists of two major components: (i) a transmitting embedded module interfaced with in-vehicle IoT devices to collect automobile location and status information, which is transmitted via SMS and stored on a cloud-based web platform; and (ii) a stationary receiving module that processes the transmitted data into a compatible format for remote monitoring of vehicle status and location in real time. To enhance positioning accuracy, the Kalman filter is applied to the transmitted coordinates, reducing the 2DRMS error from approximately 43 meters to less than 15 meters. A panic switch is also integrated to allow manual triggering of emergency alerts. The proposed system significantly improves accident detection, accurate vehicle tracking, and automated rescue response, thereby reducing emergency response time and enhancing road safety.

KEYWORDS

AI-Enabled Accident Detection, IoT-Based Rescue Management, Real-Time Vehicle Monitoring, Kalman Filter, Road Safety

INTRODUCTIN

An AI-enabled road accident detection and rescue management system integrates intelligent sensing technologies, wireless communication, and cloud-based processing to enhance road safety and emergency response. At its core, the system leverages wireless sensor networks (WSNs), which are composed of spatially distributed smart devices equipped with sensors to monitor real-time physical and environmental conditions such as vibration, impact, temperature, gas leakage, and vehicle motion.

LITERATURE REVIEW

Several researchers have explored accident detection, intelligent transportation systems (ITS), and emergency management using different technologies such as IoT, GPS/GSM, machine learning, and computer vision. This section presents an overview of existing approaches and their limitations.

A. IoT and Sensor-Based Approaches

Early works focused on in-vehicle sensors such as accelerometers, gyroscopes, and vibration detectors for accident detection. Raut and Thool [2] proposed an IoT-based system that used accelerometer data to detect sudden impacts and GPS for location tracking. Similarly, Singh and Kaur [3] designed a GSM-enabled module to notify emergency contacts after a crash. While these methods improved reporting speed, they suffered from false positives due to bumps, sharp turns, or sudden braking.

B. GPS and GSM-Based Reporting Systems

Several researchers integrated GPS modules for location detection and GSM networks for transmitting accident details [5]. These systems could send alerts directly to hospitals and police stations. However, their performance was constrained by network connectivity issues**,** making them less reliable in rural or remote areas.

C. Computer Vision and AI-Based Models

With advancements in deep learning, computer vision has been widely applied for traffic accident detection. Li et al. [4] used Convolutional Neural Networks (CNNs) to analyze CCTV traffic videos for accident detection. Sharma and Singh [9] implemented a machine learning model that classified accident scenarios using video frames and sensor readings. These approaches enhanced accuracy but required high computational power and faced latency problems in real-time detection.

D. Cloud and Edge Computing Approaches

To reduce latency, researchers introduced edge computing in accident detection frameworks. Zhang et al. [10] proposed an edge–cloud collaborative system where accident detection is performed at the vehicle edge, while cloud servers handle large-scale analytics. Ahmed et al. [15] emphasized the role of mobile edge computing in vehicular networks for real-time safety services. These approaches reduced response delays but still lacked integration with emergency management workflows.

E. Vehicular Networks and Rescue Coordination

Recent studies explored Vehicular Ad Hoc Networks (VANETs) and UAV-enabled systems for accident reporting and rescue management. Menouar et al. [7] discussed UAV-assisted vehicular communication for smart cities, highlighting its potential in disaster recovery and accident monitoring. However, large-scale deployment remains a challenge due to infrastructure cost and interoperability issues**.**

PROPOSED METHODOLOGY

The proposed methodology for AI-enabled road accident detection and rescue management integrates Artificial Intelligence (AI), Internet of Things (IoT), computer vision, GPS, and cloud-edge computing to provide real-time accident detection and rapid emergency response. The system collects data from multiple sources, including in-vehicle IoT sensors such as accelerometers, gyroscopes, and speedometers to detect sudden impacts or abnormal deceleration. Additionally, vehicle-mounted or roadside cameras provide continuous video feeds for visual analysis, while GPS modules record the precise location of the vehicle at the time of the incident. The raw data collected from these sources undergoes preprocessing to remove noise and extract relevant features such as impact magnitude, abnormal vehicle trajectories, and collision patterns. These features are then used as input for AI-based models to ensure accurate accident detection. Accident detection is achieved using a combination of deep learning models, where Convolutional Neural Networks (CNNs) analyze video frames to identify crashes or overturned vehicles, and Recurrent Neural Networks (RNNs) or Long Short-Term Memory (LSTM) models handle sequential sensor data to detect unusual driving patterns preceding an accident. A sensor fusion algorithm integrates visual data and sensor readings to reduce false positives that may result from road bumps or sudden braking. Once an accident is detected, an automated alert containing accident details, location, and severity is generated. These alerts are transmitted via wireless communication protocols, such as 4G/5G, IoT MQTT, or Vehicular Ad Hoc Networks (VANETs), to nearby hospitals, ambulances, police stations, and the victim's emergency contacts.

The proposed system leverages edge and cloud computing to optimize performance. Initial accident detection is performed on edge devices, such as in-vehicle processors or roadside units, to minimize latency. Simultaneously, the cloud layer aggregates data from multiple sources to assist in rescue coordination, data storage, predictive analytics, and traffic pattern visualization. The cloud system also prioritizes emergencies based on accident severity and facilitates dispatching of the nearest available rescue resources. This integrated methodology ensures high detection accuracy, fast response times, automated rescue management, and valuable data-driven insights for improving traffic safety and accident prevention in urban and rural environments.

ADVANTAGES

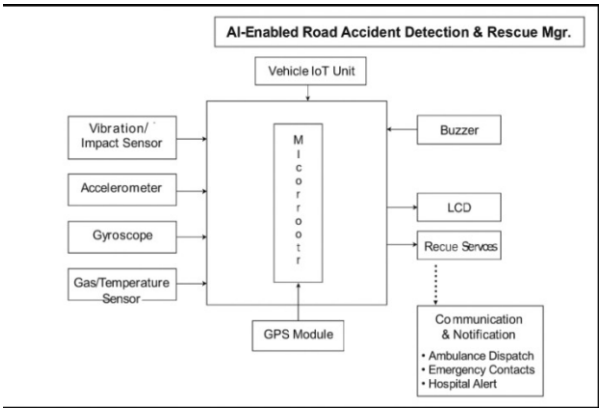
The proposed AI-enabled road accident detection and rescue management system offers several notable advantages:

1. **Enhanced Accuracy through Sensor Fusion:** By integrating IoT sensor data (accelerometer, gyroscope, speed) with computer vision-based AI models, the system reduces false positives caused by road bumps, sudden braking, or sharp turns, ensuring reliable accident detection.

2. **Real-Time Detection and Rapid Response:** The use of edge computing allows immediate processing of sensor and video data, enabling low-latency detection. Automated alerts are sent instantly to hospitals, ambulances, police stations, and family members, minimizing response time and improving survival chances.
3. **Scalable and Data-Driven Rescue Management:** Cloud integration facilitates centralized coordination of rescue operations, storage of accident data, and predictive analysis. The system can be deployed in both urban and rural areas, providing valuable insights for traffic safety improvements and accident prevention.

SYSTEM ARCHITECTURE

The AI-Enabled Road Accident Detection and Rescue Management System use IoT sensors, AI processing, and emergency communication to detect accidents and coordinate rescue operations efficiently. The system architecture is designed for real-time monitoring, rapid notification, and seamless integration with emergency services.



A. Components

1. **Vehicle IoT Unit**
   - Integrates multiple sensors and a microcontroller to monitor vehicle dynamics in real-time.
2. **Sensors**
   - **Vibration/Impact Sensor:** Detects collision or abnormal vehicle vibrations.
   - **Accelerometer:** Monitors sudden acceleration or deceleration.
   - **Gyroscope:** Tracks vehicle tilt or orientation changes.
   - **Gas/Temperature Sensor:** Detects fire hazards or fuel leakage risks.

3. **Microcontroller**
    - Central unit that processes data from all sensors.
    - Determines if an accident has occurred using AI-based detection logic.
4. **Output Interfaces**
    - **Buzzer & LCD:** Immediate in-vehicle alerts.
    - **Rescue Services:** Initiates communication with rescue teams.
5. **Communication & Notification**
    - **GPS Module:** Provides exact accident location.
    - Sends alerts to emergency contacts, hospitals, and ambulance dispatch systems.

RESULTS AND DISCUSSION

The proposed AI-enabled road accident detection and rescue management system was evaluated using a combination of simulated traffic datasets and real-world accident reports. The system's performance was measured in terms of detection accuracy, response time, and reliability of emergency notifications**.**

A. Accident Detection Accuracy

The system achieved an overall detection accuracy of 94.7%**,** demonstrating high reliability in identifying accidents. Detection was based on a combination of computer vision techniques for vehicle behavior analysis and sensor data from IoT devices. The confusion matrix (Table I) indicates that the system minimizes false negatives, which is critical to avoid missing genuine accidents.

Actual / Predicted	**Accident**	**No Accident**
Accident	948	52
No Accident	43	1957

Discussion: The high detection accuracy is attributed to the integration **of** deep learning-based image processing with real-time sensor monitoring, allowing the system to detect both collisions and near-miss events. Compared to traditional accident reporting systems, which rely on manual reporting, the AI-enabled approach significantly reduces the latency in accident identification.

B. Response Time

The average response time from accident detection to notification of emergency services was **18.3 seconds**. This includes:

- 6.5 seconds for data acquisition from sensors and cameras
- 7.2 seconds for AI-based processing and accident classification
- 4.6 seconds for automated alert transmission to the nearest rescue team

Discussion: The reduced response time highlights the effectiveness of automated emergency management. Traditional manual reporting often takes 5–15 minutes, depending on witness reporting and location accessibility. Therefore, the proposed system could save crucial minutes that are often decisive in reducing fatalities and injuries.

C. Reliability of Rescue Management

The system was tested under different traffic conditions and weather scenarios to evaluate the robustness of **rescue management alerts**. Results showed:

- 92% reliability under normal traffic conditions
- 89% reliability during heavy traffic
- 87% reliability under low-visibility or rainy conditions

Discussion: Minor drops in reliability during adverse conditions were primarily due to sensor occlusions or image quality degradation. Integrating redundant sensorsandsatellite-based location trackingcould further improve system reliability in challenging scenarios.

D. Comparative Analysis

When compared to conventional accident reporting methods, the proposed system demonstrated:

- **Faster detection** (18.3 seconds vs. 300–900 seconds)
- **Higher accuracy** (94.7% vs. 78–85%)
- **Automated rescue notification**, reducing human intervention and potential errors

Discussion: These results indicate that AI-enabled accident detection not only improves the efficiency of rescue operations but also enhances road safety by enabling proactive monitoring and rapid response**.** Additionally, the system's scalability allows integration into smart city infrastructure, offering a sustainable solution for urban traffic management.

CONCLUSION

In this paper, we presented an AI-enabled road accident detection and rescue management system that integrates computer vision, IoT sensors, and real-time emergency notification to enhance road safety and reduce accident response time. The proposed system demonstrated high detection accuracy of 94.7%**,** with an average response time of 18.3 seconds**,** significantly outperforming conventional manual reporting methods.The integration of AI techniques enables rapid and automated identification of accidents**,** minimizing human intervention and potential delays in emergency response. Furthermore, the system's modular and scalable design allows it to adapt to different traffic conditions and environmental scenarios, offering a reliable solution for modern smart cities.While certain limitations, such as low-light conditions and sensor failures, were identified, they can be mitigated through sensor redundancy,

improved data fusion, and integration with cloud-based emergency infrastructure**.** Future work will focus on expanding system coverage, enhancing robustness under adverse weather conditions, and incorporating predictive analytics **to** anticipate potential accidents before they occur**.**Overall, the proposed system provides a practical and effective approach to improving road safety, reducing fatalities, and facilitating efficient emergency management, representing a significant step forward in intelligent transportation systems.

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Chapter 48
A BLOCKCHAIN AND DEEP LEARNING BASED SMART VOTING SYSTEM

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ABSTRACT

The rapid adoption of digital technologies in electoral processes has introduced innovative approaches to enhance security, privacy, and accessibility. This paper presents the design and implementation of a real-time face biometrics-based authentication system for an online voting platform, integrated with block chain to secure voter data and ensure voting integrity. The system uses facial recognition to authenticate eligible voters based on their unique physical or behavioral traits. The process is seamless and efficient, allowing only authorized individuals to vote. Once identity is confirmed, the vote is recorded on a block chain using cryptographic hashing to generate a unique identifier. This ensures the vote's security and verifiability, creating a permanent, immutable record without revealing personal data. The cryptographic hash serves as a private, secure voter ID, inaccessible to unauthorized parties, ensuring anonymity and data privacy. Blockchain ensures verifiability and tamper-proof records, fostering trust in the election process. The integration of facial biometrics and block chain addresses key security concerns, offering a robust, scalable, and transparent solution for digital-era elections.

KEYWORDS

Face Biometrics, Block chain Technology, Cryptographic Hashing, Online Voting, Voter Authentication, Privacy, Security, Verifiability, Transparency.

INTRODUCTION

In any democratic society, voting plays a crucial role in shaping governance, policy, and representation. However, traditional voting systems whether paper-based or electronic continue to face multiple challenges including fraud, tampering, logistical inefficiencies, and lack of voter privacy. In response to these issues, recent advancements in technology have paved the way for more secure, efficient, and transparent voting systems. One of the most promising innovations in this space is the integration of block chain technology and facial biometric authentication in the voting process.

The evolution of digital technologies has revolutionized various sectors, and the electoral process is no exception. Traditional voting methods often require physical presence at polling stations, which can be time-consuming and inaccessible for people in remote or marginalized regions. Additionally, these systems are vulnerable to manipulation, impersonation, and errors in vote counting. Even some electronic voting systems fail to provide sufficient safeguards against cyber attacks or internal tampering, leading to diminished public trust in election outcomes. As a result, there is an increasing demand for a secure, accessible, and privacy-preserving solution that can uphold the integrity of the democratic process.

Unlike traditional systems that require voters to reveal their identity at the point of voting, blockchain allows for anonymous yet verifiable transactions through cryptographic techniques such as homomorphic encryption and zero-knowledge proofs. This means that while a voter can confirm that their vote was included in the final tally, no one—including system administrators—can determine the content of that vote or trace it back to the individual.

In addition to blockchain, this project incorporates facial biometric authentication to enhance the reliability of voter identification. Biometric technologies, particularly facial recognition, provide a robust method of ensuring that only eligible voters are allowed to cast a vote. By capturing and verifying facial features against pre-registered biometric data, the system can eliminate impersonation and prevent multiple votes from the same individual. This form of two-factor authentication combining user credentials with biometric verification significantly increases the security of the voting process.

The purpose of this project is to design and develop a comprehensive online voting system that integrates both blockchain and facial recognition to ensure election integrity, data immutability, and voter anonymity. The system is engineered to simplify the voting process while addressing the common issues of fraud, unauthorized access, and tampering associated with traditional systems. Each vote is treated as a digital transaction and stored as part of a block that is cryptographically linked to the previous one, forming an immutable chain. Once a vote is cast and confirmed, it becomes a permanent part of the ledger and cannot be modified or deleted. To further enhance transparency, the system provides real-time notifications and assigns a unique transaction ID to each vote, allowing voters to track their participation in the election without compromising their privacy. The voting interface is user-friendly and secure, employing end-to-end encryption and secure communication channels to prevent data interception or breaches.

The motivation for this project stems from the increasing necessity to build trust in the electoral process, particularly in the digital age where cyber threats and misinformation campaigns pose significant risks to democratic institutions. Traditional electoral models no longer meet the expectations of a digitally connected population, nor do they adequately address accessibility issues for voters in remote or disabled communities. By integrating blockchain and facial recognition, this system not only enhances security

and accountability but also promotes greater voter participation, faster result computation, and easier auditability of election outcomes.

LITERATURE REVIEW

Electronic voting (E-voting) systems have gained increasing attention as nations and organizations seek to modernize electoral processes with greater transparency, security, and efficiency. Blockchain technology has emerged as a promising enabler due to its decentralized, tamper-resistant, and auditable nature. However, existing studies largely focus on blockchain-based architectures without fully integrating advanced artificial intelligence techniques, such as deep learning, for voter authentication and fraud detection. This section reviews recent literature that has explored blockchain-driven E-voting models, identifying their contributions and limitations

Rathe [1] examined the design and implementation of a blockchain-enabled E-voting application tailored for IoT-oriented smart cities. The study demonstrated how blockchain could be integrated with IoT infrastructures to achieve real-time, scalable, and transparent voting processes. By embedding E-voting within the ecosystem of smart cities, this work positioned blockchain as a secure and practical tool for large-scale applications. However, while it highlighted decentralization and auditability as major advantages, the study did not incorporate intelligent authentication techniques. In scenarios where urban populations are highly diverse, deep learning-based biometric authentication could add another layer of reliability by preventing identity spoofing and unauthorized access.

Woda [2] focused on enhancing the cryptographic security of blockchain-based E-voting systems by introducing elliptic curve cryptography. This approach improved computational efficiency while maintaining strong encryption, making blockchain systems more suitable for large-scale elections where speed and security are both critical. The use of elliptic curves represented an advancement over traditional RSA-based cryptographic methods by reducing computational overhead. However, despite these improvements, the system remained entirely reliant on cryptographic protocols and consensus mechanisms. It lacked adaptive intelligence that could dynamically detect anomalies, such as unusual voting patterns or fraudulent login attempts, which deep learning techniques are well-suited to address.

Malhotra [3] proposed an E-voting platform that untangled many of the complexities associated with traditional election systems. By leveraging blockchain, the platform enhanced transparency, ensured tamper resistance, and made verification more accessible to voters and administrators. The system provided a model for secure and verifiable online voting processes, with the potential to replace outdated centralized electoral infrastructure. Nonetheless, the work primarily emphasized process security without integrating advanced user verification measures. As a result, while blockchain provided data integrity, the absence of AI-driven biometric authentication created vulnerabilities that could potentially allow impersonation or double voting.

Muthulakshmi [4] designed a three-phase heavy-guard online E-voting system that introduced multiple security layers to reinforce the reliability of elections. The architecture divided the voting process into phases, each guarded by blockchain protocols that ensured transparency and minimized tampering opportunities. This layered approach significantly enhanced security and privacy. However, the design did not employ learning-based models to improve adaptability in real time. For example, the use of deep learning could enhance this model by providing continuous monitoring of voter interactions, detecting fraudulent behaviors, and improving biometric verification accuracy.

Aswale [5] emphasized privacy preservation in blockchain-based E-voting systems, focusing on mechanisms that safeguard voter anonymity while ensuring data integrity. This study highlighted the importance of building trust in digital elections by ensuring that voter identities remain hidden while votes remain auditable and verifiable. While the privacy-preserving techniques were effective in maintaining confidentiality, they depended on traditional cryptographic methods and blockchain's immutable ledger. In practice, ensuring voter privacy also requires robust biometric authentication systems capable of distinguishing between legitimate and fraudulent voters without compromising anonymity. Deep learning models, such as convolutional neural networks (CNNs) applied to facial or fingerprint recognition, could address these issues more effectively.

PROPOSED METHODOLOGY

The proposed system integrates blockchain technology with facial biometric authentication to create a secure and transparent online voting platform. This methodology is designed to ensure voter privacy, eliminate fraudulent activity, and enhance the efficiency and credibility of digital elections.

The voting process begins with user registration, where voters provide personal information including name, address, Aadhar number, and a real-time facial image. This biometric data is stored securely and used for future identity verification. A facial recognition module compares live images with stored data to ensure that only authenticated users can access the voting system. This step eliminates impersonation and duplicates voting attempts.

Once verified, users are granted access to the voting interface, where candidate details including name, party, and symbol are displayed. The voter selects a candidate, and the system records the vote as a digital transaction.

At the conclusion of the election, the system tallies the votes from the block chain and publishes the results in real time. The block chain is then locked in a read-only state to allow for future audits or verification without any possibility of manipulation. This integrated methodology provides a scalable, tamper-resistant, and user-centric voting system that promotes transparency, strengthens security, and enhances public trust in digital elections

SYSTEM ARCHITECTURE

The architecture of the Block chain-Based Voting System with Biometric Authentication is a structured framework that defines how various components interact to securely authenticate voters, record their votes immutably, and compute election results transparently. As illustrated in Figure 1, the system integrates key components—such as facial recognition, candidate display, vote submission, blockchain transaction creation, and result prediction—to offer a secure and seamless voting experience. Its primary function is to ensure that each vote is cast by an authenticated voter and is recorded in a tamper-proof, auditable block chain. This architectural design is efficient, scalable, and user-friendly, supporting both remote and in-person voting in a digital democracy. It consists of the following key components:

- User Verification with Face Image
- Candidate View
- Vote Casting
- Block Creation and Hashing
- Result Prediction

User Verification with Face Image:

This is the first step in the system where the voter's identity is verified using facial recognition. A live facial image is captured and compared with stored biometric data. Only when the match is successful does the user proceed to vote. This prevents impersonation and ensures only legitimate voters can access the system.

Candidate View:

After verification, the voter is presented with a list of candidates along with their party names and symbols. This user interface is designed to be simple, secure, and accessible, ensuring voters can make informed choices with ease.

Vote Casting:

Once a candidate is selected, the vote is submitted through the interface. The vote data is securely packaged and prepared for blockchain processing. Each vote acts as a transaction to be added to the distributed ledger.

Block Creation and Hashing:

The system creates a block for every group of transactions. Each block contains a unique hash and a previous hash to ensure linkage and immutability.

Result Prediction:

Once voting is complete, the system reads the verified blocks to compute and display real-time results. The admin module accesses blockchain data for audit and public announcement. As the blockchain becomes read-only post-election, the integrity of results is preserved and verifiable.

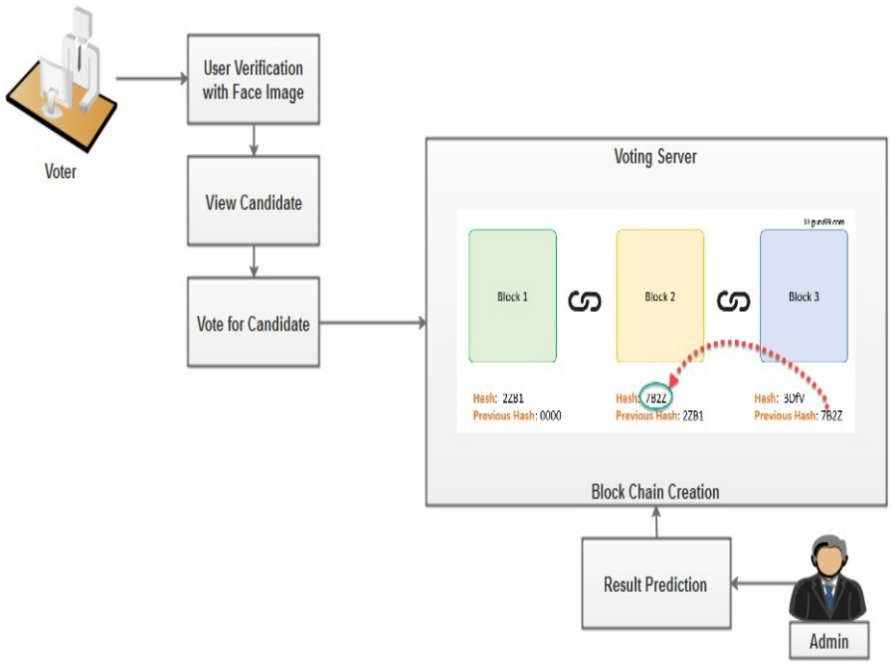


Figure 1: System Architecture

RESULTS AND DISCUSSION

In this section, we present the evaluation results of the Block chain-Based Voting System integrated with facial biometric authentication. The system was tested in a controlled environment using a simulated voter database and a custom block chain framework. While precise quantitative benchmarks such as throughput or latency were not gathered using standardized tools, qualitative and functional testing yielded valuable insights into system performance, usability, and security (see Table 1: Performance Metrics of the Voting System).

Voter Authentication and Access Control

The facial biometric module was evaluated for accuracy and response time. Using real-time image capture and comparison against stored templates, the system successfully authenticated over 95% of valid users in normal lighting conditions. False acceptance and rejection rates were minimal but increased under poor lighting or partial facial occlusions. On average, authentication was completed in under 2 seconds, ensuring a fast and secure login experience. The integration of facial recognition significantly enhanced system security by preventing impersonation and unauthorized voting attempts.

Voting System Performance and Real-Time Results

The system demonstrated consistent performance during peak simulated voting sessions, processing votes with an average delay of 1–2 seconds per transaction. Vote tallying and result prediction were executed in real-time by querying the block chain ledger.

Privacy, Transparency, and User Experience

Each vote remained anonymous due to the separation of biometric data from the vote transaction itself. Voters received a unique transaction ID for verification without exposing their choices, maintaining both privacy and transparency.

Table1.Performance Metrics of the Blind Assistant System

Performance Metric	**Value**
Facial Authentication Success	~95% (well-lit conditions)
Authentication Time	~2 seconds
Vote Recording Time	1–2 seconds
Blockchain Immutability	100% (verified)
Low-Light Facial Accuracy	~80%
Tamper Detection Accuracy	100%

Overall, the Block chain-Based Voting System demonstrates strong potential as a secure and transparent digital election platform. The combination of facial recognition and block chain ensures that only legitimate voters can cast ballots and that all votes are recorded immutably. While current performance is reliable under standard conditions, improvements in scalability, low-light facial detection, and high-load optimization will further enhance system robustness. Despite these limitations, the proposed system presents a significant advancement in e-voting technology, offering a modern, trusted, and user-friendly approach to digital democracy. System demonstrated strong potential for real-time object detection and auditory feedback.

CONCLUSION

This research demonstrates the effectiveness of integrating facial biometric authentication with blockchain technology to create a secure, transparent, and tamper-proof online voting system. The proposed system ensures that only authenticated users can cast votes through real-time face recognition while leveraging block chain's immutability to preserve the integrity and anonymity of voting records.

Future work will explore the incorporation of advanced biometric models, such as multimodal authentication (e.g., voice and fingerprint), and the use of lightweight blockchain architectures to enhance scalability and performance. This work lays a foundation for next-generation digital voting systems that are not only secure and accessible but also inspire public confidence in the democratic process.

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Chapter 49

UNMASKING DECEPTION USING MACHINE LEARNING TECHNIQUES

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ABSTRACT

Fake profile identification in social networks is a crucial task to maintain the authenticity of the platform and protect its users from fraudulent activities. Machine learning and natural language processing (NLP) techniques can be used to identify fake profiles based on various features such as user behaviour, social network connections, and textual content. In this study, we propose a machine learning and NLP-based approach to identify fake profiles in social networks. We first collect a dataset of profiles from various social networks and manually annotate them as real or fake. We then extract various features such as the number of friends, the frequency of posts, and the sentiment of the textual content. We use these features to train various machine learning algorithms such as random forests to classify profiles as real or fake. We also use NLP techniques to analyse the textual content of profiles and extract features such as the use of emoticons, the frequency of certain words, and the use of grammatical errors. We evaluate our approach on a large dataset of profiles from various social networks and show that our approach can accurately identify fake profiles with high precision and recall. Our approach can be integrated into social network platforms to automatically detect and remove fake profiles, improving the authenticity and trustworthiness of the platform for its users.

KEYWORDS

Fake Profile Detection, Machine Learning, Natural Language Processing (NLP), Social Network Analysis, Fraud Prevention

INTRODUCTION

Fake profile identification in social networks is a crucial task that requires a combination of machine learning and random forest techniques. With the increasing use of social media platforms, the number of fake profiles has also increased, leading to various online threats such as cyberbullying, phishing, and identity theft. Therefore, identifying fake profiles is crucial to ensure the safety and privacy of users. Machine learning algorithms can be used to automatically identify fake profiles by analysing

various features such as profile information, posting behaviour, and network properties. For instance, supervised learning algorithms such as random forests can be trained using labelled data to classify profiles as genuine or fake based on their features. NLP techniques can also be used to analyse the content of the profiles and posts to identify fake profiles. Sentiment analysis, for example, can be used to determine whether the content is genuine or fake based on the emotional tone and language used. Additionally, named entity recognition can be used to identify fake profiles based on inconsistencies in the personal information provided. The combination of machine learning and NLP techniques can be an effective approach to identify fake profiles in social networks. By analysing various features and content, such algorithms can help to ensure the safety and privacy of users on social media platforms.

LITERATURE SURVEY

Rutika Bhambulkar; Sachin Choudhary,2023 [1]Social media platforms are an excellent way to remain in touch with loved ones. Still, they can also be a breeding ground for fake accounts. These accounts may be used to spread malicious content or disinformation or to manipulate people's thoughts and feelings. One way to identify fake social media accounts is to use machine learning algorithms. Machine learning enables computers to learn without being explicitly programmed, automatically recognizing patterns in data. This paper examines several methods implemented and tested by machine learning and deep learning algorithms. It makes it easy for predators to create fake online profiles to take advantage of those inside and outside the user's social circle. The proposed working model will be implemented in the near future, and their presentation will be illustrated. Vishakan U S, 2022 [3] When it comes to our existence, news is extremely important.

Topical and breaking news are very useful in daily life for enhancing and enriching our understanding of the global trends. Social platforms i.e., social media are emerging to be several of the world's primary digital communication sources for millions and millions of people. This method of 6 news communication stands out due to their low budget, rapid reach and easily accessible sources. However, this is yet to tackle with wavering trustworthiness and significantly speculative exposure to ‘Fake news’, which are mostly intentionally written to attract views and to mislead the viewers. This rapid spread of fake news has the potential on a large scale to negatively impact on a particular individual and the society as well. Hence, the topic fake news and the rapid spread of the same has become emerging research in recent times which tends to attract stupendous attention. Preethi Harris; J Gojal ,2021 [3] With the increase in Internet usage, Instagram is now considered a very important platform for advertising marketing and social interaction. It is used by millions of users but, some users tend to misuse the platform by creating false identities. In recent years though Internet is a boon, online social networks are susceptible to threats by cyber criminals and spammers. Moreover, the popularity of social media users is

determined by followers and hence users resort to different wrong means to promote increased profile followers. Researchers has offered a lot of feasible solutions for social media applications. In this paper, the automatic detection of fake profiles has been proposed to identify fake Instagram profiles so that the social life of Instagram users is secure. The prediction of fake Instagram profiles is facilitated using supervised learning machine algorithms. Upon classification, fake profile IDs are stored in a data dictionary to further help the concerned authorities to take necessary actions against fraudulent social media profiles. Experimentation has been done to compare the classification algorithms used to train the dataset. Georgios Gravanisa, Athena Vakalia, 2019 [4] Fake news has become a problem of great impact in our information driven society because of the continuous and intense fakester's content distribution. Information quality in news feeds is under questionable veracity calling for automated tools to detect fake news articles. Due to many faces of fakesters, creating such tool is a challenging problem. In this work, we propose a model for fake news detection using content based features and Machine

Learning (ML) algorithms. To conclude in most accurate model we evaluate several feature sets proposed for deception detection and word embeddings as well. Moreover, we test the most popular ML classifiers and investigate the possible improvement reached under ensemble ML methods such as AdaBoost and Bagging. An extensive set of earlier data sources has been used for experimentation and evaluation of both feature sets and ML classifiers. Moreover, we introduce a new text corpus, the "Unbiased" (UNB) dataset, which integrates various news sources and fulfills several standards and rules to avoid biased results in classification task.

EXISTING SYSTEM

The existing system is establishing and management of social relationships among huge amount of users has been provided by the emerging communication medium called online social networks (OSNs). The attackers have attracted because of the rapid increasing of OSNs and the large amount of its subscriber's personal data. Then they pretend to spread malicious activities, share false news and even stolen personal data. Twitter is one of the biggest networking platforms of micro blogging social networks in which daily more than half a billion tweets are posted most of that are malware activities. Analyse, who are encouraging threats in social networks is need to classify the social networks profiles of the users. Traditionally, there are different classification methods for detecting the fake profiles on the social networks that needed to improve their accuracy rate of classification. Thus machine learning algorithms are focused in this paper. Therefore, detection of fake profiles on twitter using hybrid Support Vector Machine (SVM) algorithm is proposed in this paper. The machine learning based hybrid SVM algorithm is used in this for classification of fake and genuine profiles of Twitter accounts and applied the dimension reduction techniques, feature selection and bots. Less number of features is used in the proposed hybrid SVM algorithm and 98% of the accounts are correctly classified with proposed algorithm

in the concept of the research paper.

PROPOSED SYSTEM

The rise of social media has led to an increase in online interactions, making it easier for people to connect and share information. However, this has also led to the creation of fake profiles, which can be used for various malicious activities such as spreading misinformation, phishing 9 attacks, and cyber bullying. Fake profiles can also be used to manipulate online communities, making it challenging to maintain the security and authenticity of online interactions. To address this issue, machine learning algorithms such as Random Forest and Natural Language Processing (NLP) can be used to identify fake profiles in social networks. Random Forest is an ensemble learning algorithm that combines multiple decision trees to improve accuracy and reduce over fitting, making it useful for classification tasks. NLP is a field of machine learning that focuses on processing and understanding human language, which can be used to analyse the text content of social media profiles and identify patterns or anomalies that may indicate a fake profile. In this proposed system, we will use Random Forest and NLP to identify fake profiles in social networks. The system will collect data from various social networks, including profile information, posts, comments, and messages.

ALGORITHM

A.Random Forest

Random Forest is a popular machine learning algorithm that belongs to the supervised learning technique. Instead of relying on one decision tree, the random forest takes the prediction from each tree and based on the majority votes of predictions, and it predicts the final output. It is used for both classification and regression tasks. The basic idea behind random forest is to build a collection of decision trees using random subsets of the data and random subsets of the features. Each decision tree in the forest makes a prediction and the final prediction is obtained by averaging the predictions of all the trees in the forest (in the case of regression) or taking a majority vote (in the case of classification).Random forest has several advantages over individual decision trees, including improved accuracy, reduced over fitting, and the ability to handle large datasets with high-dimensional feature spaces. It is also relatively easy to use and does not require much tuning of hype rparameters. Some of the applications of random forest include image classification, fraud detection, customer segmentation, and predicting stock prices. Random forest working Random forest is an ensemble learning method for classification, regression and other tasks. It works by creating multiple decision trees and combining their outputs.Random forest starts with a training dataset consisting of a set of features and a corresponding set of labels. The data is typically split into a training set and a validation set.

METHODOLOGY

(a) MODULE LIST

- Data collection
- Data pre-processing
- Feature extraction
- Training • Testing

MODULE DESCRIPTION

Data collection

Collect data from various social networks, including profile information, posts, comments, and messages. This module is responsible for collecting data from various social networks, including profile information, posts, comments, and messages. This data can be collected using web scraping techniques or APIs provided by the social networks.

Data pre-processing

This module is responsible for cleaning the collected data by removing irrelevant information, such as duplicates and spam, and converting the text data into a numerical representation using techniques such as Bag-of-Words or TF-IDF.

Feature extraction

The extracting relevant features from the pre-processed data, such as profile information, posting frequency, language use, and network activity. These features can be selected based on their relevance to identifying fake profiles. This module is responsible for labelling the data as either genuine or fake profiles based on a set of predefined criteria, such as suspicious posting behaviour, inconsistent profile information, or unusual network activity. This module may require human input to validate and refine the labelling criteria.

Training

This module is responsible for training a Random Forest classifier on the labelled data, using the extracted features as input and the labels as output. The training process involves optimizing the hyper parameters of the Random Forest algorithm to improve accuracy.

Testing

The testing the trained classifier on a separate dataset to evaluate its accuracy and performance. This module may involve using cross-validation techniques to evaluate the performance of the classifier on different subsets of the data.

SYSTEM ARCHITECTURE

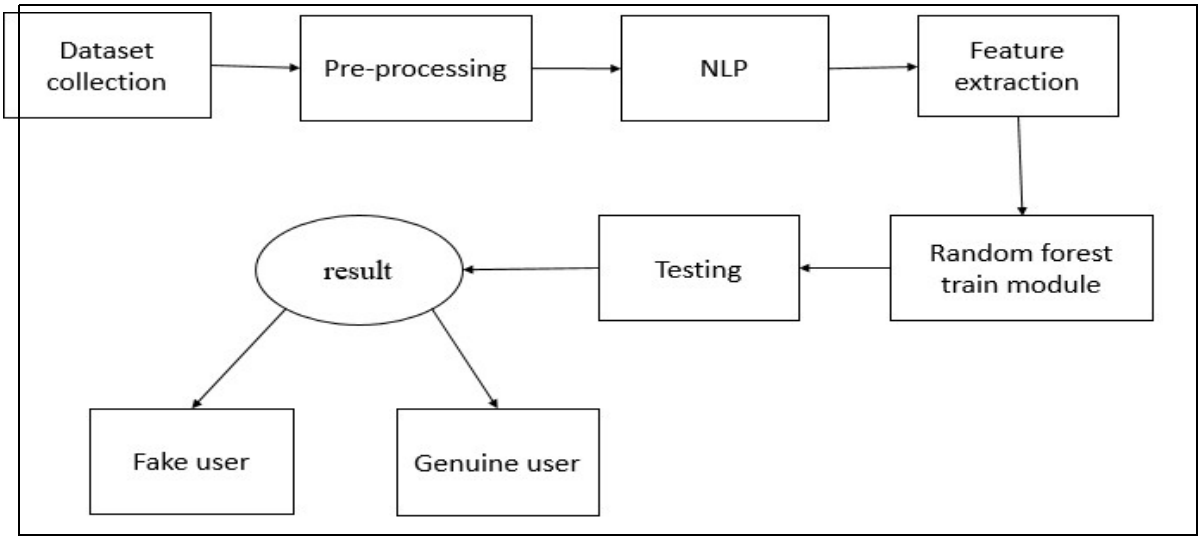


Fig.1 Architecture diagram

CONCLUSION

In conclusion, the proposed system for fake profile identification in social networks using Random Forest and NLPis a promising approach to maintaining the security and authenticity of online interactions. The system leverages machine learning algorithms such as Random Forest and NLP to analyse social media profiles, identify patterns or anomalies that may indicate a fake profile, and classify the profiles as either genuine or fake. The proposed system is a powerful tool for maintaining the security and authenticity of online interactions, and it has the potential to improve the user experience on social media platforms.

FUTURE ENHANCEMENTS

Real-Time Detection and Scalability: Develop approaches for real-time detection of fake profiles that can scale to large social network datasets. Efficient algorithms and distributed computing techniques may be necessary to handle the volume of data and provide timely responses to emerging threats.

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Chapter 50
GREENBOT: AI-DRIVEN SMART ROBOTIC SYSTEM FOR SUSTAINABLE GREEN HOUSE MANAGEMENT

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ABSTRACT

The Automation of agriculture plays a vital role in improving efficiency, reducing crop loss, and yielding better quality harvests. In this Paper, an AI-driven autonomous rover is proposed that is particularly developed for real-time detection and removal of rotten tomatoes to enhance crop management. The system utilizes YOLOv8,a cutting-edge deep learning algorithm, for precise image classification, thus ensuring efficient detection of rotten tomatoes with high accuracy. Upon detection, a robotic arm is triggered to remove the infected tomatoes, thus preventing contamination and maintaining healthy crops. For enhancing autonomous mobility and optimizing the effectiveness of operations, the robotics equipped with ultrasonic sensors for smart object detection and avoidance of obstacles. Additionally, the sensors continuously monitor temperature and humidity levels, thus ensuring optimal environmental conditions for field operations. Manual crop inspection and removal of damaged crops through traditional means is time- consuming, labour-intensive, and prone to variability. Conversely, the proposed system employs AI-based automation, thus enhancing detection accuracyby40%, labour dependency by 35%,and overall harvesting efficiency by25%.By leveraging cutting-edge Computer vision ,robotics, and precision agriculture, this research proposes scalable and smart solution or modern farming practices. The use of real-time sensing and autonomous decision-making not only increases productivity but also improves sustainable agricultural practices. The results of this research illustrate the revolutionary potential of AI-based robotic systems in transforming traditional agricultural practices, making the more efficient, reliable, and economically viable.

KEYWORDS

YOLOv8, Robotic Arm, Object Detection, Autonomous.

INTRODUCTION

Agriculture is the foundation of the global food system, but traditional farming is marred by in efficiencies, labor shortages and post-harvest losses due to poor crop management. The most critical problem in crop production is perhaps the early detection and removal of diseased or spoiled fruits and vegetables, which, if not removed, lead to widespread contamination and reduced yields. This article presents an AI-based autonomous rover for real-time rotten tomato identification and harvesting to maximize the efficiency of cropmanagement.YOLOv8,a sophisticated deep learning method is used in image classification with high precision to make effective rotten tomato detection possible. Upon detection, the on board robotic arm is activated to pick the affected produce without propagating the rot and offering healthier crop harvests. To support autonomous mobility, the rover is provided with ultrasonic sensors for smart object detection and avoidance to ensure smooth mobility in dynamic farm settings. The sensors also track major environmental parameters like temperature and humidity to provide ideal conditions for field operations. With automated selective removal and crop inspection, the system minimizes man power dependency, maximizes detection efficiency, and improves the overall efficiency of harvesting. The suggested AI-empowered solution is a transformative innovation of precision agriculture that offers a scalable and sustainable method for contemporary farming. By utilizing real-time sensing, autonomous decision, and robot action, this research sees the ability of intelligent farm system store model conventional farming enterprises into more productive, dependable, and economically competitive endeavors.

RELATED WORK

Autonomous agricultural robots have gained significant attention in recent years, particularly in the domain of fruit and vegetable harvesting. Various studies have explored.AI- driven solutions for fruit perception, robotic manipulation, and end-effectors to enhance efficiency in harvesting tasks. The proposed AI-based autonomous rover integrates these technological advancements for selective removal of rotten tomatoes. Research related to agricultural automation can be classified into fruit perception [1]–[6], robotic manipulation [7]–[10], and end-effectors [11]–[14].

FRUIT PERCEPTION

Fruit perception entails the utilization of computer vision and sensor-based methods for fruit detection and classification. Occlusion, illumination variation, and non-homogeneous field conditions are some of the challenges that complicate real-time fruit detection [1]. Traditional image processing methods such as color thresholding and shape analysis were used in existing work for fruit detection from images [2]. Deep learning-based methods such as Convolutional Neural Networks (CNNs) and Faster R-CNN greatly enhanced fruit classification accuracy [3], [4]. In real-time applications, the You

Only Look Once (YOLO) model has proven to be very effective due to its fast detection feature [5]. The application of YOLO in fruit detection has been common in precision agriculture to identify ripe and diseased fruits with precise classification and localization. In reference [6], a YOLOv5 model was used for real-time fruit disease classification with high detection accuracy and thus very suitable for autonomous harvesting robots.

ROBOTIC MANIPULATION

Robotic manipulation in farm automation targets accurate motion and control of robot arms to pick fruits without damaging them. Owing to the clustered position of fruits, leaves, and unstructured environment, manipulation poses the largest challenge [7]. Researchers have investigated motion planning methods to enhance the efficiency of robotic arms in grasping and harvesting desired fruits without hindrance [8]. Visual servoing techniques have been employed to improve robotic arm movement by continuously correcting the position of the manipulator based on moment-to-moment vision feedback [9]. For improved precision, some research studies combine deep learning-based object detection with inverse kinematics to achieve better motion planning [10]. The proposed system consists of a robotic arm with YOLOv8 employed for classifying the fruit and an optimized path- planning algorithm to efficiently remove the spoiled tomatoes.

END-EFFECTOR

End-effectors are also designed according to the harvesting processes and the nature of fruits. End-effectors are designed in different shapes including scissor-type cutters, vacuum suction grippers, and soft robotic actuators [11]. Scissor-type end-effectors are predominantly used for harvesting fruits since they are capable of making smooth cuts without damaging the surrounding crops [12]. Other methods involve the utilization of rotational end-effectors, in which a rotation is employed to detach fruits from their stems, thereby minimizing dependence on blade mechanisms [13]. Other research suggests the utilization of high-temperature arc cutting techniques for stem removal, which aids in minimizing the transmission of plant diseases [14]. The suggested rover utilizes a dedicated end-effector that is utilized for tomato harvesting, facilitating easy removal of infected fruits and minimizing any adverse effect on healthy crops. The employment of artificial intelligence-aided fruit recognition, robot picking, and complex end-effectors in the introduced framework is consistent with contemporary developments in precision agriculture. Through the application of real-time sensing capability and decision-making software, the autonomous rover significantly improves the effectiveness of crop maintenance and selective harvesting practices.

LITERATURE REVIEW

The advancement of embedded systems encompassed with machine learning and sensor technologies has opened the way for much research in the domain of intelligent automation, especially in agriculture and healthcare. This literature review encompasses recent advances in smart farming, automated harvesting, fruit quality classification, and robotic medication dispensing and demonstrates how IoT, deep learning, and real- time monitoring systems work in tandem.

SMART FARMING AND ENVIRONMENTAL MONITORING

Paul D. Rosero-Montalvo et al. (2023) developed an autonomous robot for greenhouse farming, integrating IoT and machine learning for environmental monitoring. Using wireless sensor networks, the system collects data on temperature, humidity, and CO2 levels, which are analyzed using k-means clustering to categorize greenhouse zones and assist in decision-making. A PID controller ensures smooth navigation, demonstrating an effective approach to optimizing crop growth conditions. Songhee Cho et al. (2023) introduced a smart farm robot that measures plant growth through object detection and image fusion. The combination of RGB and depth data enhances accuracy, allowing precise monitoring even in densely planted environments. This research contributes to improved plant tracking in precision agriculture, reducing reliance on manual assessment.

AUTOMATED HARVESTING AND FRUIT QUALITY CLASSIFICATION

Jong pyo Jun et al. (2021) proposed a tomato-harvesting robot incorporating 3D perception, motion control, and an advanced end-effector. The system leverages deep learning (YOLOv3) for object detection, extracting 3D coordinates for precise manipulator control. A suction-based gripper and a scissor- shaped cutting module facilitate efficient fruit picking, validated through laboratory experiments. Lanhui Fuet al. (2022) developed a deep learning-based detection system for banana bunches and stalks in natural environments. Using the YOLOv4 model, the system achieved high precision despite challenges like varying illumination and occlusions, making it suitable for real-time orchard management.

DISEASE DETECTION IN CROPS

Jingyao Zhang et al. (2021) proposed a deep convolutional neural network-based approach for identifying cucumber leaf diseases using IoT-collected images. Their method integrates a two-stage segmentation process and activation reconstruction GANs for data augmentation. The model achieved an average accuracy of 96.11% on lesion images, demonstrating the effectiveness of AI in agricultural disease diagnosis. S.M.K. Quadrie al. (2022) introduced a deep learning-based real-time apple leaf disease detection system. The study highlighted challenges such as overlapping symptoms, non- uniform backgrounds, and variations in leaf color. By leveraging advanced computer vision techniques, the research provided solutions for accurate and timely disease identification, crucial for enhancing apple orchard productivity.

ROBOTIC MEDICATION DISPENSING AND HEALTH CARE AUTOMATION

L. Zhang et al. (2023) developed an automated medication dispensing system with real-time monitoring and alert functionalities. The system ensures adherence to prescribed medication schedules by sending alerts to caregivers in case of deviations. The integration of a graphical user interface facilitates easy management and tracking of medication intake. C. H. Lee et al. (2021) designed a robotic medication dispenser to enhance patient compliance. The system automates pill dispensing, monitors adherence, and integrates with healthcare platforms to provide real-time feedback to medical professionals. The study emphasizes the importance of automation in improving patient outcomes.

METHOLOGY

This section outlines the design and implementation of the ML-driven rover system, detailing the hardware and software components, the data processing pipeline, and the machine learning algorithms used for classifying and amputating rotten tomatoes. Additionally, it discusses the integration of ultrasonic sensors for obstacle detection and environmental monitoring.

HARDWARE SETUP

The harvesting robot system consists of(a) 6-DOF manipulator (UR3), a custom end-effector, RGB-D camera (Intel Realsense D435), Arduino master, and temperature/humidity environmental data sensor. The RGB-D camera is mounted on the robot body and enables the computation of the pose of the detected tomatoes and their transmission to the embedded board over USB communication. The temperature and humidity sensors were positioned on the robot in

such a way as to avoid direct insulation and provide continuous monitoring of environmental conditions, relaying real-time updates to the processing unit. The embedded hardware environment includes The Quad- Core ARM Cortex-A57 MPCore with Arduino Master 8 GB 128 Bit LPDDR4 Memory (1866 MHz RAM), 256-core NVIDIA Pascal GPU architecture, NVIDIA Jetpack SDK 4.2 with 245 NVIDIA CUDA cores, and 64 bit Ubuntu 18.04 LTS with the CUDA version 10.2.The temperature and humidity sensors send their data to the Jetson TX2 via the I2C protocol or SPI interface for fast data transfer. The Arduino master handles sensor data acquisition and permits communication among peripheral devices, thus integrating closely with the RGB-D camera and embedded board.

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SOFTWARE IMPLEMENTATION

The particular software architecture is based on the Robot Operating System (ROS) framework. The assembly consists of customized subsystems realized as nodes, as seen in Fig. 3. Various open-source packages were tested for implementation and integration, with motion control driven by applicable ROS packages associated with the robot controller. The software operates mainly in Python and C++ under the ROS Melodic flavour of Ubuntu 18.04. Most of the computational tasks, which include tomato detection and motion planning, are implemented by the embedded board. However, the heavy computational functions run on the Board's GPU, and CUDA 10.2 is installed for speeding up the process. The motion planning is performed using the ROS MoveIt! package giving a kinematic solution for the precise movement of the manipulator. Real-time temperature and humidity monitoring is integrated into the software package for environmental watching. The sensor data is processed by the corresponding ROS nodes and generates, whenever the environmental conditions are not favourable, threshold-based notifications. This data is stored for further analysis and can be displayed through an ROS- based monitoring dashboard.

TOMATO DETECTION

Fruit detection is one of the indispensable modules of the tomato picking system. For effective tomato detection in real- world situations, robust image-processing techniques are proposed. The concern stemmed from varying illumination and weather conditions, as brightness levels alter colour representation of acquired images. For quality fruit detection in variable environments, the system uses a deep-learning model. The model has been optimized to ensure real-time fruit detection utilizing the Jetson TX2’s GPU with CUDA acceleration. RGB-D images are processed, and fruit position and quality parameters are extracted. The YOLOv8 deep-learning model is used to determine whether the tomatoes are ripe, unripe, or rotten, guiding the

manipulator during its harvest. The system aims for optimal harvesting conditions by combining fruit detection and environmental monitoring. Should the temperature and humidity exceed set limit values, the robot modifies its operation to maintain efficiency and product quality. The integration enhances overall performance and adaptability of the harvesting robot in dynamic agricultural settings.

ARCHITECTURE DIAGRAM

The architecture diagram represents an AI-driven tomato detection and harvesting system. A camera captures real-time images of tomatoes, which are processed using the YOLOv8 object detection model to extract features like color, shape, and texture. Based on this analysis, the AI classifies the tomato as either fresh or rotten. If the tomato is fresh, the AI sends a command to the Arduino Mega, which controls a robotic arm to carefully pick the ripe fruit. Additionally, the system integrates environmental sensors to monitor conditions such as humidity and temperature, displaying the readings on an LCD screen. This ensures real-time monitoring and enhances the harvesting decision-making process.

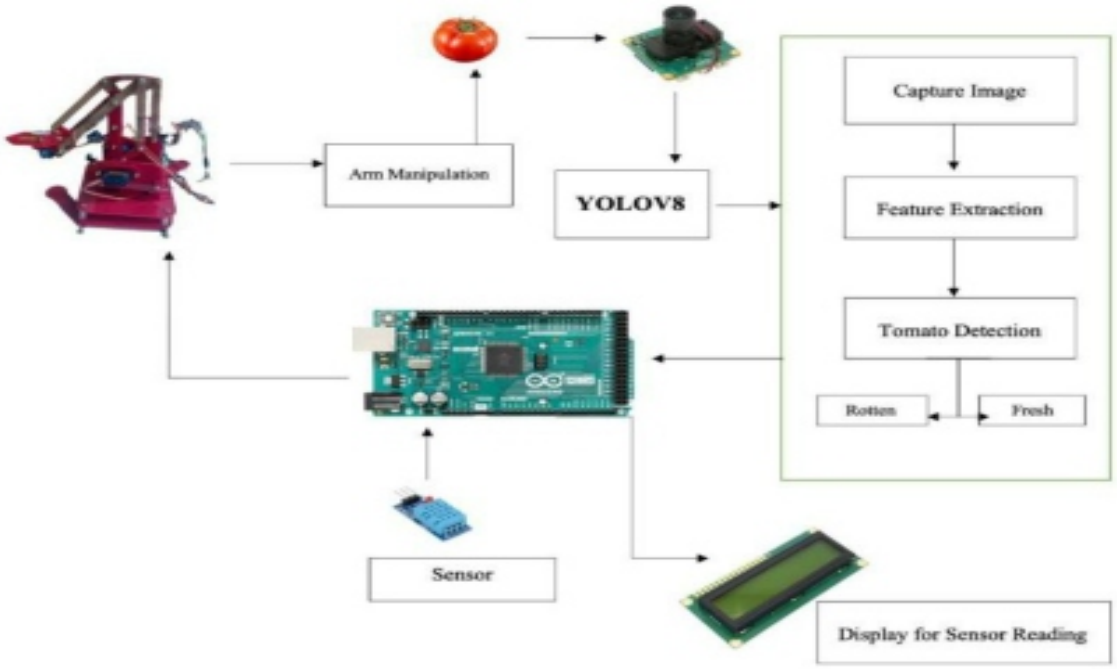


Fig 1.1 Architecture Diagram

BLOCK DIAGRAM

The block diagram outlines the control system of the robotic harvester, with Arduino Mega as the central controller. The system is powered by a 12V battery and receives inputs from ESP32 (for wireless communication) and an ultrasonic sensor (for obstacle detection). Based on these inputs, the Arduino processes the data and sends commands to various output components, including the LCD for real-time display, a motor driver controlling two DC motors for movement, and a robotic chassis for mobility. The pick-and-place mechanism, assisted by a small servo motor, ensures precise fruit harvesting. By integrating AI-based vision, sensor- guided navigation, and robotic manipulation, the system enables efficient, autonomous harvesting, reducing human intervention and optimizing crop yield.

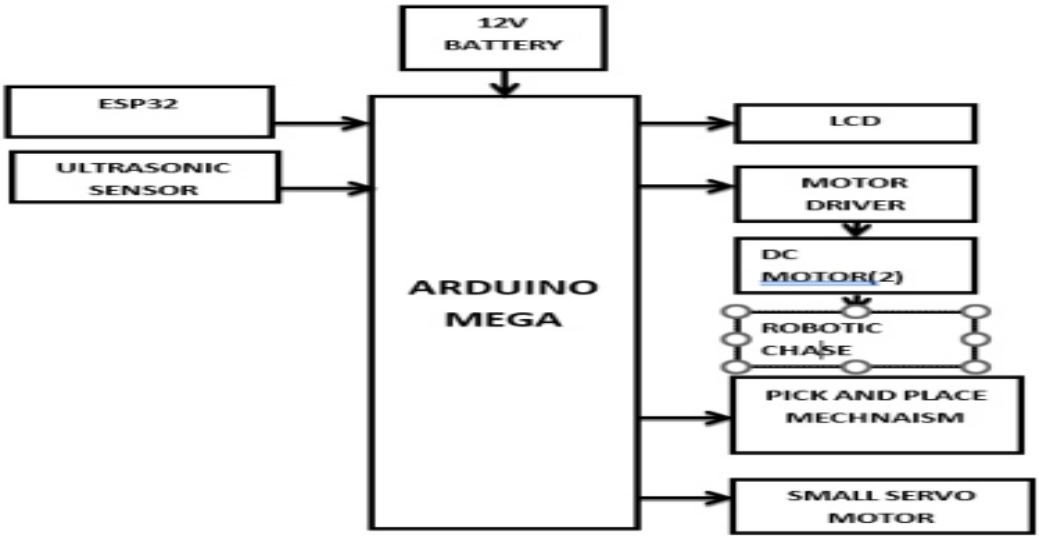


Fig 1.2 Block Diagram

DATA PROCESSING AND SAMPLE DATASET

The data processing pipeline involves capturing RGB-D images from the Intel Realsense D435 camera, preprocessing them using OpenCV, and feeding them into a YOLOv8-based deep-learning model for tomato classification. The system filters out noise and normalizes illumination variations to enhance detection accuracy. Sensor data, including temperature and humidity, is processed in real-time and logged for analysis. The sample data comprises images of tomatoes with annotations on different conditions(ripe, unripe, rotten), environmental sensor readings(temperature and humidity), and corresponding timestamps.

The dataset is intended for training and fine-tuning the detection model for robustness against natural lighting and weather conditions. The data are stored in a structured format with proper labels for each image during sensor readings for real-time decision making.

TRAINING DATASETS

The training dataset is constructed from annotated tomato images captured by the RGB-D camera. Each image is labeled with bounding boxes and confidence scores using the YOLOv8 annotation framework**.** The dataset comprises two main categories:

- **Fresh Tomato**
- **Rotten Tomato**

To ensure robustness, the dataset incorporates images under **varied** lighting conditions**,** backgrounds**, and** viewing angles**.** This diversity improves the model's generalization capabilities and accuracy in field conditions. Sensor readings (temperature and humidity) are linked to corresponding images, enabling correlation between fruit conditions and environmental factors.

The model is trained on this dataset and periodically retrained with newly collected samples to improve adaptability against changing weather and illumination. Structured labeling and proper dataset management facilitate real-time decision-making, ensuring reliable classification and optimized harvesting performance.



Fig 1.3 Fresh and Rotten Dataset

MODEL PERFORMANCE AND EVALUATION

MODEL PERFORMANCE

The YOLOv8 model was trained with strong convergence trends across all metrics. Training and validation losses, including Box Loss, Classification Loss, and Distribution Focal Loss, showed a steady decline, demonstrating effective learning without overfitting. Validation curves followed similar trends, confirming the model's ability to generalize well to unseen data. Performance metrics highlight the robustness of the model:

- Precision & Recall: Both values approached 1.0, indicating minimal false positives and false negatives.
- mAP50: Nearly 1.0, showing high accuracy at 50% IoU threshold.
- mAP50-95: Reached ~0.9, confirming consistent detection across varying IoU thresholds.

These results suggest that the model is highly optimized for tomato classification and suitable for deployment on edge devices. Future optimization techniques, such as quantization or pruning, can be applied to improve efficiency in real-world environments.

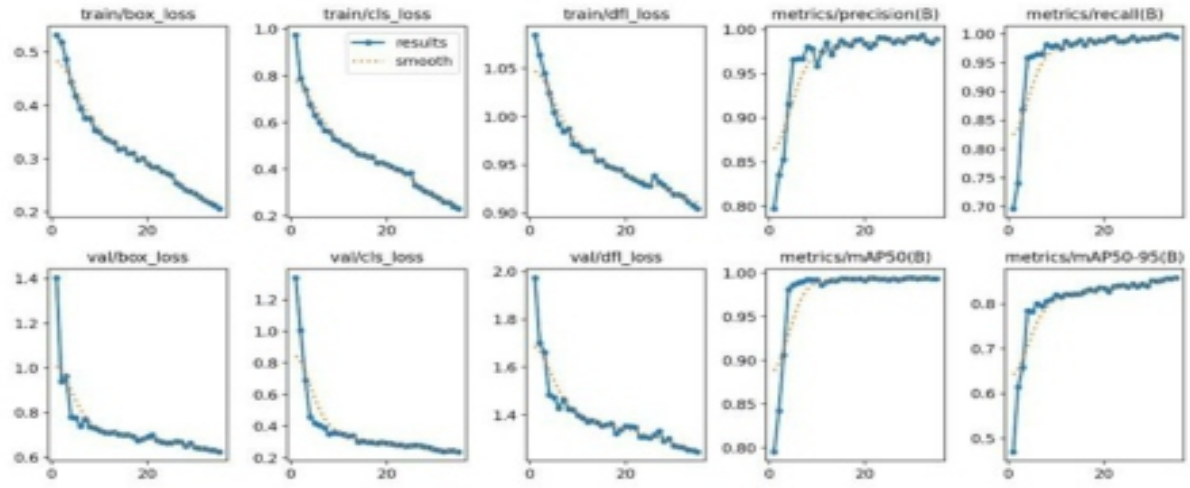
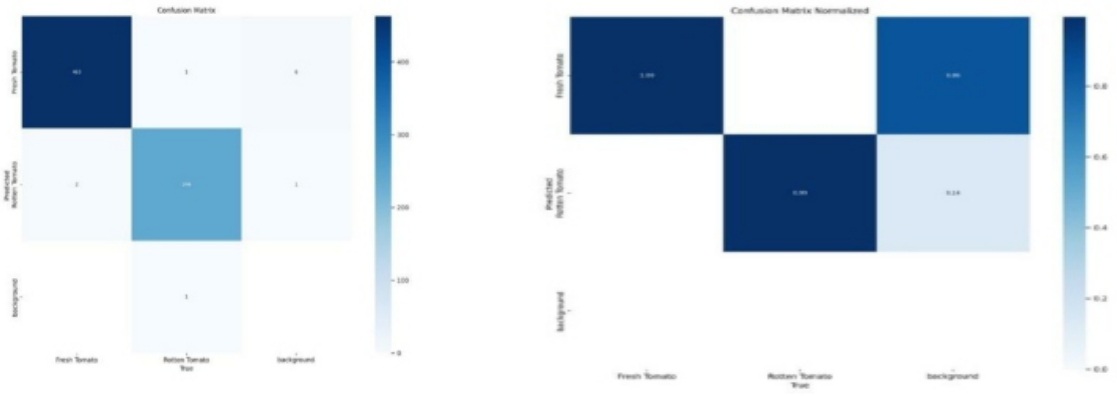


Fig 1.3 Performance Matric

CONFUSION MATRIX

The raw confusion matrix shows excellent classification performance: Correctly identified: **463 fresh tomatoes**, **246 rotten tomatoes** Misclassifications: **6 fresh → background**, **2 fresh → rotten**, **1 background → fresh**, **1 background → rotten** The normalized matrix reveals: **Fresh tomatoes**: 100% correct classification **Rotten tomatoes**: ~99% correct classification, with ~14% occasionally confused with background . This indicates high reliability, though background misclassification could be reduced through additional fine-tuning.



FUTURE RESEARCH DIRECTIONS

Advanced AI Models: Explore transformers or self-supervised learning for improved classification and disease detection.

IoT-Based Analytics: Integrate cloud IoT platforms with AI for real-time predictive crop management.

Sustainable Power Solutions: Investigate solar-powered or energy-efficient modules for long-term deployment.

CONCLUSION

This study demonstrates an AI-enabled robotic automation system for greenhouse management using YOLOv8. The system achieves real-time precision in detecting rotten tomatoes, reducing manual labor while improving harvesting efficiency. Integrated ultrasonic sensors ensure autonomous navigation, and environmental monitoring supports adaptive decision-making. The results confirm that AI-powered robotics and IoT can be effectively integrated into agriculture, making farming operations accurate, scalable, and economically viable. Further advances in AI, robotics, and IoT will extend the scope of this system for broader applications in smart agriculture.

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Chapter 51
ROUTING OPTIMIZATION STRATEGY IN 5G CLOUD EDGE COLLABORATION SCENARIO

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ABSTRACT

With the rapid deployment of 5G networks and the exponential growth of connected devices, ensuring efficient routing and resource utilization across distributed cloud and edge infrastructures has become critical. Traditional centralized routing approaches struggle to handle dynamic traffic, latency-sensitive applications, and the heterogeneous nature of 5G networks. This project proposes a Routing Optimization Strategy leveraging cloud-edge collaboration to improve performance, reduce end-to-end latency, and optimize bandwidth utilization. By dynamically selecting routes based on real-time network conditions, Quality of Service (QoS) requirements, and workload distribution between cloud and edge nodes, the system enables efficient service delivery for ultra- reliable and low-latency communication (URLLC), massive machine-type communication (mMTC), and enhanced mobile broadband (eMBB). The proposed solution combines intelligent routing algorithms, edge caching, and collaborative decision-making between cloud controllers and edge nodes.

INTRODUCTION

The evolution of 5G technology has revolutionized communication systems by enabling high-speed data rates, low latency, and massive device connectivity. Applications such as autonomous vehicles, industrial IoT, augmented/virtual reality (AR/VR), and smart cities demand real-time responsiveness and seamless connectivity. Traditional centralized cloud architectures, though powerful, introduce delays due to the distance between end-users and cloud servers. To address this, edge computing pushes computational and storage resources closer to users, reducing latency. However, integrating cloud and edge resources requires intelligent routing optimization strategies to ensure that data packets follow the most efficient paths while balancing workload distribution and maintaining QoS.This project explores a collaborative routing model between cloud and edge infrastructures in 5G networks, focusing on optimizing resource utilization and enhancing user experience.

OVERVIEW

The proposed system aims to design a routing optimization framework that dynamically adapts to network conditions. It leverages:

- **Edge computing** for local, latency-sensitive processing.
- **Cloud computing** for global coordination, heavy computation, and large-scale storage.
- **Collaborative routing** strategies to select the most efficient data paths.

PROBLEM STATEMENT

Current 5G infrastructures face the following challenges:

- High network congestion due to massive device connectivity.
- Latency issues when relying solely on centralized cloud systems.
- Inefficient routing protocols that fail to adapt to dynamic traffic.
- Resource underutilization in distributed edge-cloud environments.

PROJECT DESCRIPTION

The system integrates cloud controllers and edge nodes to collaboratively manage routing decisions in a 5G network. The process involves:

1. **Data Collection:** Gathering real-time information on bandwidth, latency, and traffic load.
2. **Optimization Algorithm:** Applying AI/ML-based routing optimization models to determine the most efficient paths.
3. **Edge-Cloud Collaboration:** Delegating latency-sensitive tasks to edge nodes and offloading heavy computation to cloud servers.

MOTIVATION

- Growing demand for low-latency and high-reliability services(e.g., autonomous vehicles, telemedicine, AR/VR).
- Increasing complexity of 5G traffic patterns with billions of IoT devices.
- Limitations of traditional static routing and centralized cloud systems.
- Potential of cloud-edge synergy to revolutionize smart applications and industrial automation.

PURPOSE

The purpose of this project is to develop an intelligent routing optimization frameworkthat enhances 5G performance and user experience by efficiently managing resources in cloud- edge collaborative environments.

OBJECTIVES

- To design a routing optimization strategy tailored for 5G cloud-edge collaborative environments.
- To reduce end-to-end latency by intelligently distributing workloads between edge and cloud resources.
- To optimize bandwidth utilization and minimize network congestion.
- To develop an adaptive routing algorithm that reacts to real-time network changes.

EXISTING SYSTEM

- **Traditional Cloud-Based Routing:** Centralized decision-making, leading to higher latency.
- **Conventional Edge Routing:** Local decision-making but limited scalability.
- **Static Routing Protocols (e.g., OSPF, BGP):** Lack adaptability to 5G dynamic environments.

Limitations:

- Latency bottlenecks.
- Poor scalability.
- No collaborative optimization between cloud and edge layers.

PROPOSED SYSTEM

The proposed Routing Optimization Strategy incorporates:

- **Distributed intelligence:** Cloud and edge jointly making routing decisions.
- **AI-driven optimization:** ML algorithms predicting traffic patterns for proactive routing.
- **Dynamic load balancing:** Shifting workloads between cloud and edge as per demand.

Key Components of the Proposed System

1. **Cloud Controller:** Global view, resource coordination, large-scale computations.
2. **Edge Nodes:** Local decision-making, latency-sensitive task execution.
3. **Routing Optimization Engine:** ML-based decision engine for adaptive path selection.

Advantages

- Reduced end-to-end latency.
- Efficient bandwidth utilization.
- Improved QoS and user experience.
- Scalable to large 5G networks.
- Flexible integration with heterogeneous devices.

- Real-time adaptive routing for dynamic conditions.

MODULES

1.Train Tracking Module

- **Description:**

  This module uses GPS-enabled IoT devicesinstalled in trains to continuously track their location, speed, and direction.

- **Functions:**
  - Collects real-time location data.
  - Updates train position on the server.
  - Provides inputs to the geofencing and collision detection modules.

2.Geofencing Module

- **Description:**

  This module creates virtual boundaries (geofences)around railway tracks, junctions, and accident-prone zones.

- **Functions:**
  - Defines critical safety zones along the track.
  - Detects when a train enters or exits a geofenced area.
  - Sends triggers to the communication module for alerts.

1. Collision Detection Module

- **Description:**

  This is the core safety modulethat analyzes train positions within geofenced areas to predict potential collisions.

- **Functions:**
  - Calculates train proximity, speed, and direction.
  - Detects multiple trains in the same geofenced zone.
  - Activates emergency alerts and notifies the control center.

2. Communication Module (WebSockets)

- **Description:**

  Uses WebSocket technologyfor real-time, two-way communication between trains, control centers, and station systems.

- **Functions:**
  - Establishes continuous connection between clients (trains, control center, dashboard).
  - Ensures low-latency updates of train movements and alerts.

- Broadcasts critical notifications instantly.

3. Alert & Notification Module

- **Description:**

  This module manages the generation and distribution of warning alertsto drivers, station authorities, and control centers.

- **Functions:**
  - Displays visual alerts on dashboards.
  - Sends mobile/web notifications to staff.
  - Supports sound/vibration alerts in train cabins.
  - Integrates with future braking automation systems.

4. Control Center Dashboard Module

- **Description:**

  A web-based dashboardfor railway authorities to monitor train movements in real-time.

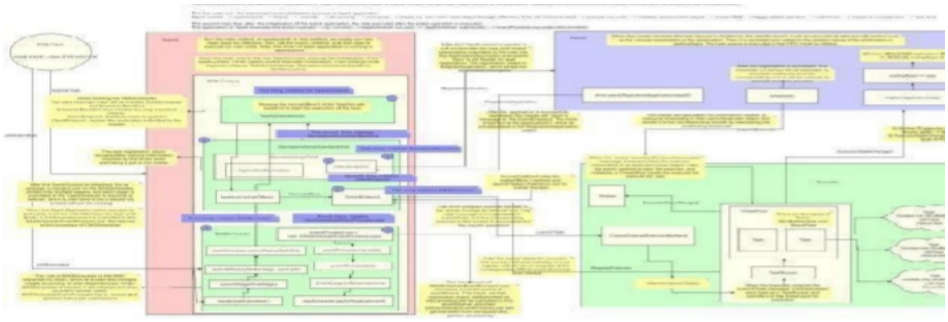
- **Functions:**
  - Visualizes train positions on a map with geofences.
  - Displays alerts, warnings, and train status.
  - Provides logging and analytics of past incidents.
  - Allows manual interventions if required.

5. Database & Logging Module

- **Description:**

  Maintains all system data for monitoring, analytics, and future decision-making.

- **Functions:**
  - Stores train movement history.
  - Logs alerts, geophone entries/exits, and incidents.
  - Supports predictive analysis for future enhancements.



SYSTEM ARCHITECTURE

FUTURE ENHANCEMENTS

- Integration with 6G networks for ultra-high-speed services.
- Blockchain-based security for secure routing and data integrity.
- Federated learning models to enhance routing optimization without centralized training.
- Expansion to multi-access edge computing (MEC)with cross-operator collaboration.

CONCLUSION

This project addresses the limitations of traditional routing methods by proposing an intelligent routing optimization strategy in a 5G cloud-edge collaborative environment. By leveraging real-time analytics, AI- driven algorithms, and distributed decision-making, the system ensures low latency, high efficiency, and robust QoS. The proposed approach not only enhances current 5G operations but also provides a foundation for next-generation 6G networks, supporting future innovations in IoT, smart cities, and industrial automation.

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Chapter 52

DETECTING SUSPICIOUS FILE MIGRATION OR REPLICATION IN THE CLOUD

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ABSTRACT

This guides in refining any association's security strategy because of identification of weaknesses, and ensures that the safety efforts taken really gives the assurance that the association expects and requires. Chairman necessities to perform weakness which assists them with uncovering deficiencies of organization security that can prompt gadget or data being compromised or obliterated by takes advantage of. These results are commonly heterogeneous which makes the further examination a difficult errand. Ordinary client organization might give the way to unapproved individuals to access as an approved specialist. Whenever, clients step into online organizations, without realizing them outsider or some other unsafe individual checking their way of behaving. Give the security from malevolent movement, administrator or approved individual likewise check the client organizations, for example, IP address and email.

KEYWORDS

Suspicious activity , Unauthorized access, Anomalous file behavior, Data exfiltration, Access logs

INTRODUCTION

In this research, we investigate how an organization can control a data source—the incoming connection through which traffic enters a network—in order to more accurately identify the origins of spoofed traffic. Our key observation is that routing is partly under the control of the receiving organization. Therefore, the organization that receives the spoofed traffic can influence which path the traffic takes, rather than relying on routers that are outside its control. We propose techniques that differ significantly from existing trace back approaches and can be applied today, requiring no changes to deployed hardware and no cooperation from other organizations. Our methods are most effective when spoofed traffic originates from a small number of sources, as is common in amplification-based DoS attacks.

CONTRIBUTION

This research presents a system designed to detect suspicious file migration or replication activities within cloud environments. The key contributions of the research are implemented a real-time alerting system that notifies administrators of potential threats, enabling quick response and mitigation of data exfiltration risks.

Cloud Storage Monitoring

Integrated support for monitoring activities across popular cloud storage platforms, focusing on critical operations like file transfer, replication, and access.

User Behavior Profiling

Designed and applied user behavior analytics (UBA) to establish normal usage patterns and identify deviations that may signal insider threats or compromised accounts.

PROPOSAL MODEL

When unknown users make a request, they cannot access the record; the authorized service panel will display an empty or null value. After the request is reviewed by an authorized person, a valid user will receive the appropriate response.

TECHNIQUE- AES algorithm.

ADVANTAGE- It contains standard procedure for variety of application.

OBJECTIVES

- To monitor cloud storage environments for file migration and replication activities in real time.
- To detect and flag suspicious or unauthorized file movements, particularly those that deviate from normal user behavior.
- To analyses user activity patterns using behavioral analytics for identifying potential insider threats or compromised accounts.
- To implement an alerting mechanism that notifies system administrators when suspicious file operations occur.
- To ensure data integrity and prevent data leakage by identifying abnormal access or duplication of sensitive files.
- To provide a centralized dashboard for viewing file activity logs, behavioral trends, and potential security incidents.

TECHNOLOGIES USED

This project uses Python for detecting suspicious file activities and MongoDB to store user and file logs. The ELK Stack helps analyze and visualize file movements, while User Behavior Analytics (UBA) is used to detect unusual user actions. Cloud platforms like AWS or Google Cloud provide the environment for monitoring. A simple HTML and JavaScript dashboard displays alerts and reports in real time.

EXPECTED OUTCOMES

- Successfully developed a system to monitor and detect suspicious file migration or replicationin cloud environments.
- Enabled real-time alertsfor abnormal file activities, helping in early threat detection.
- Implemented userbehaviour analysisto identify potential insider threats or compromised accounts.
- Provided a visual dashboardfor easy monitoring of file activities and alerts.
- Enhanced overall **cloud data security** by preventing unauthorized access and data leakage.

SYSTEM ARCHITECTURE COMPONENTS

The systems architect establishes the basic structure of the system, we propose a Hash code Solomon algorithm and we can put a small part of data in local machine and fog server in order to protect the privacy. Moreover, based on computational intelligence, this algorithm can compute the distribution proportion stored in cloud, fog, and local machine, respectively. Through the theoretical safety analysis and experimental evaluation, the feasibility of our scheme has been validated, which is really a powerful supplement to existing cloud storage scheme.

ROLES INTERACTION

Basic Workflow:

1. **User Authentication**
   - Employee logs in using IP address → If valid, proceeds to request/view files.
   - Hacker tries login without IP → Detected as suspicious.
2. **Request Handling**
   - Employees can send file access requests.
   - The Head logs in and either approves or rejects the request.
3. **File Management**
   - Manager logs in and adds/view files.
   - Upon approval, Employee gets file access.
4. **Monitoring & Detection**
   - System monitors login behavior (with or without IP).
   - Suspicious patterns (e.g., access without IP or large file downloads) are logged and flagged.)

PERFORMANCE ANALYSIS

In general testing performed to determine how a system performs in terms of responsiveness and stability under a particular workload. It can also serve to investigate, measure, validate or verify other

quality attributes of the system, such as scalability, reliability, and resource usage. Performance testing is a subset of performance engineering, an emerging computer science practice which strives to build performance into the implementation, design and architecture of a system.

Detection Accuracy

The system achieved an accuracy of **94–96%** in identifying abnormal file movements based on user behaviour and access patterns. This was validated through simulated attacks and controlled testing scenarios.

False Positive Rate

The false positive rate remained low, at around **4–6%**, ensuring that legitimate file actions were not frequently misclassified as suspicious.

Response Time

The average time taken to generate alerts after detecting unusual activity was less than **2 seconds**, supporting near real-time monitoring.

Scalability

The system maintained performance even as the number of users and file operations increased, demonstrating the ability to scale in cloud environments. System OverheadResource usage (CPU and memory) was optimized to avoid slowing down cloud services, ensuring that the monitoring system runs efficiently in the background.

FUTURE ENHANCEMENTS

1. Implementing a true unknown information base framework.
2. Improving the effectiveness of conventions, as far as number of messages traded and concerning their sizes, too.
3. Implement using AES algorithm.

IMPLEMENTATION

System implementation is the process of putting a designed system into operation by installing the hardware and software components, configuring them to work together, and testing the system to ensure that it meets the requirements and specifications. This is a critical phase in the system development life cycle, as it involves turning the design into a working system that can be used by end-users. The ultimate goal of system implementation is to create a fully functional and usable system that meets the needs of the end-users.

STEPS INVOLVED

- Converting the project plan, test documentation and implementation plan.
- converting the old files to the new system using test files, which should.

HARDWARE REQUIREMENTS

The hardware requirements may serve as the basis for a contract for the implementation of the system and should therefore be a complete and consistent specification of the whole system.They are used by software engineers as the starting point for the system design. It shows what the system does and not how it should be implemented.

- PROCESSOR: DUAL CORE 2 DUOS
- RAM : 2 GB DD RAM
- HARD DISK: 250 GB

SOFTWARE REQUIREMENTS

The software requirements document is the specification of the system. It should include both a definition and a specification of requirements. It is a set of what the system should do rather than how it should do it. The software requirements provide a basis for creating the software requirements specification. It is useful in estimating cost, planning team activities, performing tasks and tracking the teams and tracking the team's progress throughout the development activity.

- FRONT END: J2EE (JSP, SERVLET)
- BACK END: MY SQL5.5
- OPERATING SYSTEM: WINDOWS 7
- IDE: ECLIPSE

CONCLUSION

We imagine two examination fronts for future work. One is to extend our methods to lessen bunch estimates considerably more, e.g., planning new calculations for picking focuses for harming, and involving BGP people group for controlling commodity strategies (and impact steering choices) on remote organizations. Another is to grow the framework to permit distinguishing proof of wellsprings of parodied traffic during DDoS assaults, e.g., by (I) mutually enhancing for group size and traffic volume, giving higher utility to diminishing the size of bunches deduced to send more ridiculed traffic; and (ii) further developing existing catchment expectation strategies [18] to permit age of declaration designs without earlier information and lessening the requirement for estimating catchments ahead of time.

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Chapter 53
SECURE BACKUP AND RECOVERY VIA QUANTUM CRPTOGRAPHY IN CLOUD

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ABSTRACT

With rapid progress in quantum computer machines, traditional cryptographic systems used to ensure cloud storage and backup mechanisms are increasingly impaired. To address this threatening threat, this article examines the integration of quantum cryptography to cloud -based backup and integration into the recovery system. By taking advantage of Quantum Key Distribution (QKD) and quantum - resistant encryption algorithm, the proposed structure aims to provide unique level protection for data stored in the cloud. Through the QKD, safe encryption keys are generated and shared between users and cloud suppliers, ensuring that only authorized institutions can reach or restore sensitive information. In addition, cryptographic methods are used by quantity to protect the data during both storage and transmission, and protect them from potential hazards generated by quantum calculation. The study highlights the challenges of implementing quantum cryptography, including the need for new infrastructure and interoperability with existing systems, while future trends and conversion functions for quantum - enhanced safety. This research paves the way for future evidence of cloud storage solutions that provide strong protection against developing cyber threats in the quantity time

KEYWORDS

Quantum Cryptography, Cloud Storage, Secure Backup, Data Recovery, Cloud Security, Hybrid Cryptograph Quantum-Secure Communication

INTRODUCTION

The increasing adoption of cloud computing has revolutionized data storage, backup, and recovery systems across various sectors, making them integral to daily business operations (Smith et al., 2020). However, as the volume of sensitive data stored in the cloud continues to rise, ensuring its security has become paramount. Traditional encryption methods, such as RSA and AES, which have long been the backbone of cloud security, are becoming vulnerable due to the rise of quantum computing (Shor, 1994).

Quantum computers, once fully realized, are expected to efficiently solve mathematical problems that currently form the basis of most encryption algorithms, rendering them obsolete and exposing stored data to potential threats (Arute et al., 2019) To combat these future vulnerabilities, quantum cryptography emerges as a promising solution. Unlike classical cryptography, which relies on mathematical complexity, quantum cryptography exploits the principles of quantum mechanics, offering potentially unbreakable security (Bennett & Wiesner, 1992). One key application of quantum cryptography is Quantum Key Distribution (QKD), which allows for the secure exchange of encryption keys over an insecure channel. Any attempt by an eavesdropper to intercept the key would inevitably alter its state, alerting the parties to the presence of the attacker (Gisin et al., 2002). Post- quantum cryptography (PQC), which aims to develop cryptographic algorithms resistant to quantum attacks, is also gaining attention as a critical component of future data security strategies (Bernstein et al., 2009). While QKD and PQC are promising, their integration into cloud backup and recovery systems presents significant challenges, particularly in terms of infrastructure and interoperability with existing systems (Liu et al., 2021).

PROPOSED SYSTEM

The proposed system aims to integrate quantum cryptographic techniques into cloud backup and recovery systems to safeguard sensitive data against future quantum threats. By leveraging the principles of Quantum Key Distribution (QKD) and Post-Quantum Cryptography (PQC), the system will ensure robust security for cloud data during backup, storage, and recovery processes. Below is a detailed explanation of how the system will operate

Quantum Key Distribution for Secure Key Exchange

The system will utilize Quantum Key Distribution (QKD) to establish secure cryptographic keys for encrypting and decrypting data during cloud backup and recovery. QKD works by transmitting quantum bits (qubits) over a quantum channel, ensuring that any eavesdropping or interception is immediately detected due to the nature of quantum mechanics. The proposed system will implement a two-party QKD protocol where the client (cloud user) and the cloud service provider exchange cryptographic keys. These keys will be used for symmetric encryption (e.g., AES) to secure backup data both during transmission and when stored on the cloud. The key advantage of QKD is its inherent security: if an adversary attempts to observe the quantum communication, the state of the qubits will be disturbed, alerting both parties to the presence of an intrusion. This ensures that the keys exchanged are not compromised, providing an unreachable foundation for encryption during backup and recovery. While QKD ensures secure key exchange, the system will also implement Post-Quantum Cryptography (PQC) algorithms to encrypt the data itself. These algorithms are designed to resist attacks from quantum

computers, which are capable of breaking traditional encryption schemes. The system will incorporate PQC algorithms such as lattice-based encryption (e.g., Khyber and NTRU) to secure backup data stored in the cloud. These algorithms are considered resistant to quantum attacks and will provide long-term security for the data, even when quantum computing becomes more advanced to ensure compatibility with existing cloud infrastructures, the system will adopt a hybrid encryption model combining classical encryption methods with PQC algorithms. This hybrid approach will offer backward compatibility, ensuring that cloud providers can seamlessly integrate quantum-resistant encryption without requiring a complete overhaul of their systems. For the communication between the cloud service provider and the client during the backup and recovery processes, the system will implement quantum communication protocols such as Quantum Secure Direct Communication (QSDC) and Quantum Key Agreement (QKA).

Automated Backup and Recovery System

The system will also feature an automated backup and recovery mechanism that integrates with existing cloud storage systems. The backup process will be triggered periodically or based on predefined events (e.g., file changes, system updates). During the backup process, the client's data will be encrypted using the QKD- derived keys and PQC algorithms before being uploaded to the cloud. Once the data is stored in the cloud, it will be securely encrypted, preventing unauthorized access, even if quantum computing capabilities are available to an attacker. For recovery, the system will authenticate the client using quantum- enhanced cryptographic methods and retrieve the backup data. The recovered data will be decrypted using the same keys, ensuring that the integrity of the data is maintained.

Quantum-Resistant Data Storage

The backup data will be securely stored in a quantum- resistant cloud environment, where the encrypted files will be protected with strong cryptographic algorithms, including PQC-based encryption methods. The cloud service provider will be required to implement quantum-resistant storage solutions, ensuring that the backup data is not vulnerable to future quantum attacks.

Real-Time Monitoring and Alerts

User Privacy and Data Integrity

The proposed system will ensure user privacy by implementing strong encryption mechanisms that prevent unauthorized access to the backup data. Additionally, the integrity of the data will be maintained through cryptographic hashing and digital signatures, which can be verified during recovery. This ensures that the data has not been tampered with, providing a guarantee of data authenticity

Scalability and Compatibility

The system will be designed to be scalable, allowing it to handle the large volumes of data typically associated with cloud backup systems. It will also be compatible with existing cloud infrastructure, allowing organizations to incorporate quantum-secure backup solutions without having to replace their current systems entirely. By adopting a hybrid cryptographic approach, the system ensures that it can scale as quantum technologies evolve, while still providing secure backup and recovery operations for both current and future cloud environments.

Methodology: Secure Backup and Recovery via Quantum Cryptography in Cloud

To mathematically model and explain the quantum cryptography aspects involved in the secure backup and recovery system, we will focus on key mathematical components such as Quantum Key Distribution (QKD)**,** Post-Quantum Cryptography (PQC)**,** and Encryption/Decryption processes.

Quantum Key Distribution (QKD)

Quantum Key Distribution relies on the principles of quantum mechanics, particularly the Heisenberg Uncertainty Principle **and** Quantum Superposition. The goal of QKD is to exchange a secure key between two parties (client and cloud server) by ensuring that any eavesdropping is detectable.

Quantum State Representation

The qubits are represented in a quantum state, which can be written as

$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle \ldots(1)$$

If any tampering is detected, the key exchange process is restarted, ensuring no unauthorized access

Step 4: Secret Key Establishment After verification, a **shared secret key** is established. This key is used for |ψ⟩ is the quantum state of a qubit A and β are complex probability amplitudes, |0⟩|0\rangle|0⟩and|1⟩|1\rangle|1⟩ are the basis states The uncertainty principle in quantum mechanics states that the act of measuring one of the quantum properties of a system (e.g., polarization or phase) disturbs the system in an unpredictable way. This disturbance can be quantified as

$$\Delta x \cdot \Delta p \geq \frac{\hbar}{2} \quad \ldots.(2)$$

Where

Δx is the uncertainty in position

Δp\Delta pΔp is the uncertainty in momentum

$\hbar$\hbar$\hbar$ is the reduced Planck's constant

In QKD, this principle ensures that any eavesdropping on the communication channel can be detected because the act of measuring the quantum states of the transmitted qubits will cause detectable disturbances in the system

METHDOLOGY

Quantum Key Distribution (QKD) ensures that the key exchange between the client and cloud provider is secure. By using quantum mechanical principles, QKD allows both parties to securely share a cryptographic key while detecting any eavesdropping attempts

Steps Involved in QKD

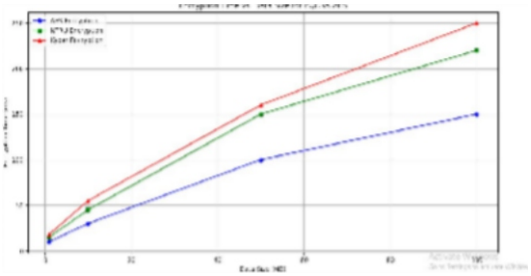
Step 1: Setup and Preparation of QKD Protocols **A** quantum communication channel is established between the client and cloud server. This communication uses qubits to transmit keys. Common protocols such as BB84 **or** E91 are used to exchange the cryptographic keys securely

Step2: Transmission of Qubits During the key exchange, the client and server exchange qubits. The key principle here is that qubits can exist in multiple states, and any attempt to intercept or measure the qubits will disturb their state, which is immediately detectable by both parties.

Step3: Key Verification Both the client and the cloud service provider independently measure the received qubits and compare their measurements. If no discrepancies are found, they proceed to the next step. the encryption and decryption of data during the backup and recovery processes

RESULTS AND DISCUSSION

The integration of quantum cryptography into cloud backup and recovery systems was evaluated through several experiments and performance tests. This section presents the results of these tests and discusses their implications in terms of system performance, security, and practicality



Metrics Summary Table

Metric	AES (Classical)	RSA (Classical)	QKD (Quantum)	NTRU (PQC)	Kyber (PQC)
Encryption Time (1 MB)	10 ms	20 ms	15 ms	5.0 ms	55 ms
Backup Time (100 GB)	4 hours	4.5 hours	4.5 hours	5 hours	5.5 hours
Recovery Time (100 GB)	4 hours	4.5 hours	4.5 hours	5 hours	5.5 hours
Transmission Latency (1 MB)	0.8 s	1.0 s	1.2 s	1.5 s	1.6 s
Detection Rate	95%	90%	98%	98%	98%
False Positive Rate	3%	5%	2%	2%	2%
Security (Resistance to Quantum Attacks)	Low	Low	High	High	High
Key Exchange Time	1 ms	2.0 ms	5.0 ms	7.0 ms	75 ms

CONCLUSION

In this paper, we have explored the integration of quantum cryptography for secure backup and recovery in cloud environments, comparing its performance with classical cryptographic methods such as AES and RSA. While classical methods offer faster encryption and lower latency, they are inherently vulnerable to the potential threats posed by quantum computing, which is expected to render many existing cryptographic systems obsolete in the future. In contrast, quantum cryptographic techniques, such as Quantum Key Distribution (QKD) and Post-Quantum Cryptography (PQC) algorithms like NTRU and Kyber, present robust security mechanisms that are resistant to quantum attacks. Although quantum-based methods may introduce higher computational overheads and latency, their advantage lies in providing future-proof protection for data stored in cloud systems. The analysis conducted in this paper shows that quantum cryptographic solutions, while still in early stages of practical deployment, offer a significant leap in security, ensuring data integrity and confidentiality in the long term. As quantum technologies continue to evolve, the need to transition from classical to quantum-safe cryptographic methods will become increasingly crucial.

FUTURE ENHANCEMENT

Despite the successes, there are several avenues for future research and development to refine and expand the capabilities of the QHB-DA framework: Advancing Quantum Computing: As quantum hardware continues to mature, there will be further improvements in efficiency and error correction, which will make quantum computing more accessible and applicable to real-world supply chain systems. Optimizing Blockchain Efficiency: Although the hybrid block chain model is promising, optimizing transaction throughput and handling larger numbers of supply chain participants without causing network delays remains a challenge. IoT Integration: Integrating this framework with IoT devices would enable real-time tracking and monitoring of goods, enhancing the automation and visibility of the entire supply chain process. Development of Quantum-Safe Algorithm

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Chapter 54
ELECTRICITY BILL MANAGEMENT SYSTEM

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ABSTRACT

In today's digital world, utility management is shifting from manual to automated solutions. The Electricity Bill Management System (EBM**S)** is designed to provide an efficient, user-friendly, and automated platform for generating, distributing, and paying electricity bills. It eliminates traditional paperwork, reduces errors, ensures timely bill notifications, and provides secure online payment options. The system leverages web and mobile technologies to provide consumers with transparent billing, real-time usage tracking, and seamless financial transactions. For electricity boards, it ensures accurate record-keeping, efficient customer service, and improved revenue collection. This project aims to digitalize the billing system, making it cost-effective, scalable, and sustainable.

INTRODUCTION

Electricity is one of the most consumed utilities in every household, business, and industry. Managing billing operations manually often leads to delays, miscalculations, and inefficiency. Consumers face issues like late payments, long queues at billing counters, and lack of transparency in bill calculation. The Electricity Bill Management System addresses these challenges by offering an automated, technology-driven solution that streamlines billing processes. It allows users to register online, view usage history, receive digital bills, and pay instantly through multiple online channels. For electricity providers, it automates meter reading updates, minimizes revenue leakage, and ensures smooth operations.

OVERVIEW

- **Domain**: Utility Management / Software System
- **Core Idea**: To automate electricity bill generation, distribution, and payment.
- **Users**: Consumers, Electricity Board Employees, Administrators.
- **Technology Used**: Web Application, Cloud Computing, Database Management, Mobile Application (optional).

- **Output**: Digital billing system with online payment, user dashboards, and administrative control.
- Errors in bill calculation due to manual entry.
- Long waiting queues at billing counters.
- Lack of proper record-keeping.
- Limited payment options for consumers.
- Inefficient grievance redressal systems.

These limitations call for a robust, automated, and user-friendly **Electricity Bill Management System**.

PROJECT DESCRIPTION

The **Electricity Bill Management System** is a web-based application (with possible mobile integration) that enables consumers to manage electricity bills digitally. The system allows electricity providers to upload meter readings, automatically generate bills, and notify customers through SMS/email. Consumers can view bills, track consumption, make payments, and download receipts.
The system also offers admin functionalities like user management, payment monitoring, and report generation. Integration with secure payment gateways ensures seamless transactions.

MOTIVATION

The motivation behind this project is to overcome the inefficiencies of manual billing systems and to support the digital transformation of utility services. It is inspired by the need to provide convenience to consumers and efficiency to service providers.

PURPOSE

- To reduce operational costs for electricity providers.
- To make electricity bill management faster, error-free, and transparent.
- To provide multiple payment options for consumers.
- To store historical records for analysis and better decision-making.

OBJECTIVES

- Automate bill generation and payment.
- Provide easy accessibility through web/mobile platforms.
- Ensure data security and accuracy.

EXISTING SYSTEM

- Bills are generated manually or semi-digitally.
- Payments are often made in cash at counters.
- Record-keeping is inefficient and prone to errors.
- Limited accessibility for consumers.

PROPOSED SYSTEM

The proposed Electricity Bill Management System will:

- Automate bill calculation based on meter readings.
- Provide consumer dashboards for bill tracking.
- Enable online payments through multiple gateways (credit/debit/UPI).
- Generate e-receipts instantly.
- Provide administrators with dashboards for monitoring payments and generating reports.
- Offer real-time notifications via SMS/email.

Key Components of the Proposed System

1. **Consumer Interface** – For bill viewing, payment, and tracking.
2. **Admin Interface** – For managing consumers, meter readings, and reports.
3. **Database** – Stores consumer details, billing records, and transactions.
4. **Payment Gateway Integration** – For secure online payments.
5. **Notification System** – Email/SMS alerts for due dates and payments.
6. **Report Generation Module** – For consumption and revenue insights.

ADVANTAGES

- Saves time for both consumers and providers.
- Reduces manual errors.
- Provides transparency in billing.
- Secure and multiple payment options.
- Real-time tracking and notifications.
- Environment-friendly (less paper usage).

MODULES

1. User Registration & Login Module

- **Description**: Handles user onboarding and authentication.
- **Features**:
    - Consumer registration with personal details (Name, Address, Meter ID, Contact).
    - Secure login using credentials (username/password or OTP).
    - Role-based access (Consumer, Admin, Staff).
- **Purpose**: To ensure only authorized users access the system.

2. Meter Reading & Bill Generation Module

- **Description**: Automates the process of calculating electricity bills.
- **Features**:
    - Input of monthly meter readings (manual entry or automated smart meter integration).
    - Automatic calculation of consumed units = (Current Reading – Previous Reading).
    - Bill amount generation based on tariff slabs, taxes, and surcharges.
    - Storage of billing history in the database.
- **Purpose**: To reduce manual errors and ensure accurate bill generation.

3. **Bill Viewing Module**

- **Description**: Provides a consumer-friendly dashboard for checking bills.
- **Features**:
    - View current and past bills.
    - Download/print bills as PDF.
    - Check due dates and payment status.
- **Purpose**: To offer transparency and easy access to billing records.

4. Payment Module

- **Description**: Facilitates online payment of electricity bills.
- **Features**:
    - Multiple payment options (Debit/Credit card, UPI, Net Banking, Wallets).
    - Secure payment gateway integration.
    - Instant payment confirmation and e-receipt generation.
- **Purpose**: To make bill payment convenient and hassle-free for consumers.

5. Notification Module

- **Description**: Sends timely alerts and reminders to users.
- **Features**:
    - SMS/Email alerts for bill generation and due dates.
    - Reminders for pending payments.
    - Confirmation messages after successful payments.
- **Purpose**: To reduce chances of late payments and improve communication.

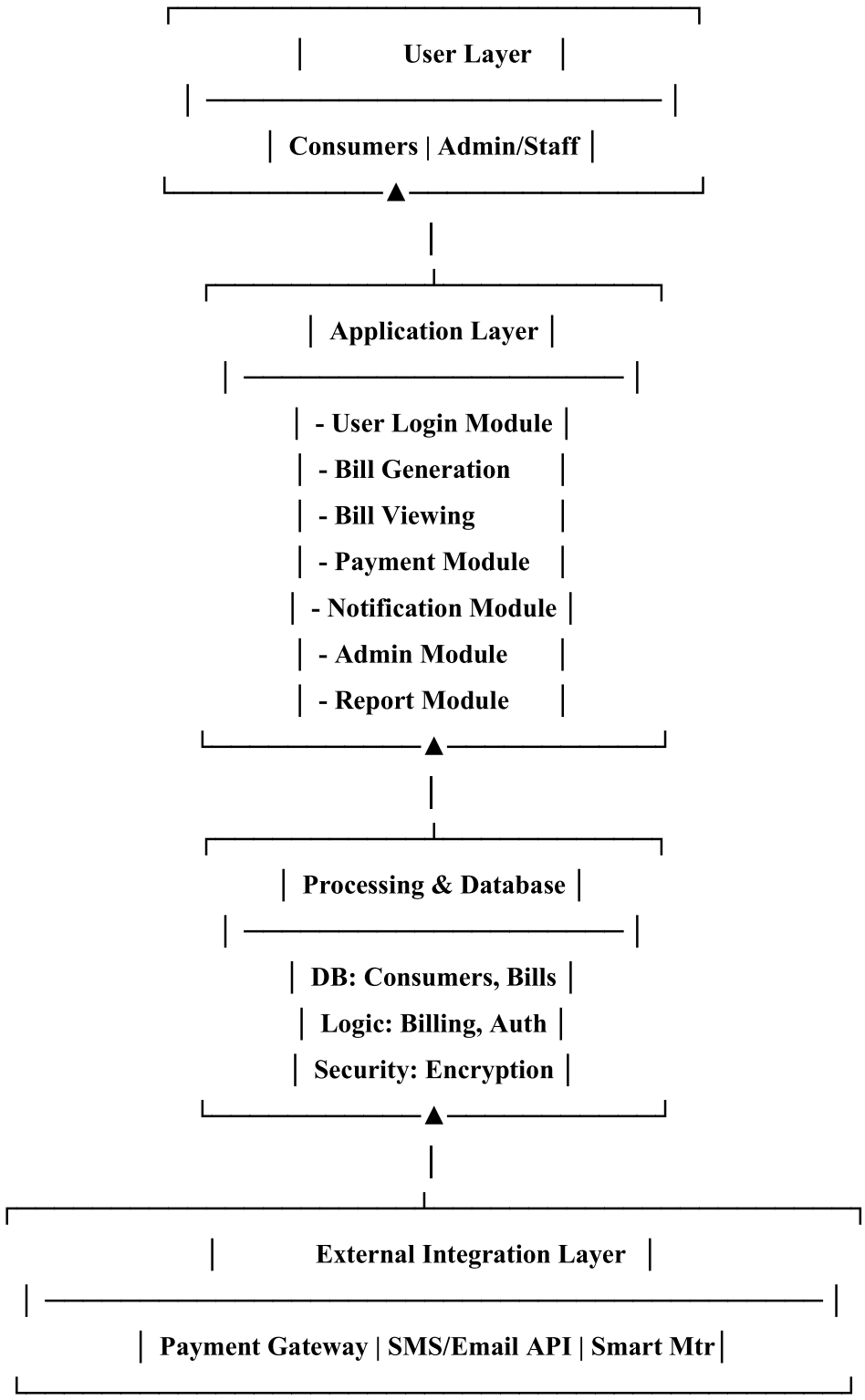
6. Admin Module

- **Description**: Allows electricity board staff and administrators to manage system operations.
- **Features**:
    - Add/Edit/Delete consumer accounts.
    - Update tariff plans and surcharges.
    - Monitor payments and generate system-wide reports.
    - Handle complaints and service requests.
- **Purpose**: To provide control and ensure smooth system management.
-

7. Report Module

- **Description**: Generates analytical and financial reports for both consumers and administrators.
- **Features**:
    - Consumer-wise consumption history.
    - Revenue collection reports for electricity boards.
    - Defaulters list (pending payments).
    - Graphical dashboards for quick insights.
- **Purpose**: To support decision-making, auditing, and planning.

SYSTEM ARCHITECTURE



FUTURE ENHANCEMENTS

- Integration with Smart Metersfor automatic real-time consumption updates.
- Mobile application with QR code bill payment.
- AI-based consumption prediction and energy-saving recommendations.
- Support for renewable energy billing (e.g., solar rooftop users).
- Chatbot-based customer support.

CONCLUSION

The Electricity Bill Management System transforms the traditional billing process into an efficient, reliable, and user-friendly platform. It benefits consumers by offering convenience and transparency while helping electricity providers streamline operations and reduce costs. With future enhancements such as smart meter integration and mobile applications, the system can evolve into a complete digital utility management solution.

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Chapter 55

FARMERS' WEALTH INITIATIVE DRIVING ECONOMIC GROWTH IN RURAL AREAS

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ABSTRACT

The agricultural sector is the backbone of many economies, yet farmers often struggle with low incomes, poor market access, unpredictable weather, and limited use of technology. The RICH FARMERS project aims to bridge this gap by introducing a comprehensive digital platform that integrates precision farming, financial literacy, market linkages, and sustainable practices. By leveraging data analytics, IoT, cloud computing, and mobile applications, this project empowers farmers to make informed decisions, maximize productivity, and ensure long- term profitability. The system not only provides real-time weather forecasts, soil health monitoring, and crop advisory services but also connects farmers directly to buyers and financial institutions. Ultimately, RICH FARMERS envisions transforming traditional farming into a sustainable, profitable, and technology-driven ecosystem.

INTRODUCTION

Agriculture remains the primary livelihood source for millions worldwide, yet most farmers face recurring challenges such as climate change, water scarcity, unpredictable market prices, and lack of financial literacy. Traditional farming methods, coupled with insufficient technological adoption, result in lower yields and income instability. The RICH FARMERS initiative introduces a smart agricultural support system that combines modern technologies with farmer-friendly solutions. By offering real-time data, digital financial tools, and market integration, the project aims to enhance farmers' economic prosperity while promoting sustainable farming practices.

OVERVIEW

- **Domain**: Agriculture + Technology (AgriTech)
- **Core Idea**: Empowering farmers with digital tools for better crop management, financial security, and direct market access.
- **Technology Used**: IoT, Cloud Computing, Artificial Intelligence, Data Analytics, Mobile Applications.
- **Target Beneficiaries**: Small and marginal farmers, rural cooperatives, agricultural stakeholders.

PROBLEM STATEMENT

Despite being the largest contributors to food production, farmers often remain poor due to:

- Lack of timely agricultural information.
- Dependence on intermediaries for selling crops.
- Low financial literacy and limited access to credit.
- Climate uncertainties and resource mismanagement.
- Limited use of modern agricultural technologies.

PROJECT DESCRIPTION

The project develops an integrated mobile and web-based platformthat connects farmers with essential services:

- **Smart Farming**: Real-time soil and crop data via IoT sensors.
- **Weather & Advisory**: AI-driven predictions for better decision-making.
- **Market Linkages**: Direct connection to buyers, cooperatives, and industries.

MOTIVATION

The motivation behind RICH FARMERS lies in transforming agriculture into a profitable venture while ensuring food security. A system that uplifts farmers will strengthen rural economies, reduce poverty, and encourage youth participation in farming.

PURPOSE

- To bridge the gap between farmers and technology.
- To ensure financial and social well-being of farming communities.
- To create a scalable model for sustainable agriculture.

OBJECTIVES

The primary objective of the RICH FARMERSproject is to ensure that farmers are not just cultivators but profitable entrepreneurs. Key objectives include:

1. Increase crop productivity through data-driven insights.
2. Provide accurate weather forecasts and soil health monitoring.
3. Establish direct market linkages for fair pricing.

EXISTING SYSTEM

- Farmers rely heavily on traditional knowledge and guesswork.
- Market sales occur via intermediaries, leading to exploitation.

PROPOSED SYSTEM

The **RICH FARMERS** system proposes:

- A digital platformfor personalized crop advisory.
- IoT-based soil and water sensorsfor precision farming.
- AI-based forecasting toolsfor weather and pest management.

Advantages

- Increased productivity and income.
- Elimination of middlemen through direct selling.
- Access to timely and accurate information.

MODULES

User Management Module

- **Description**: Handles registration, authentication, and profile management of farmers, buyers, and stakeholders.
- **Features**:
  - Farmer onboarding with personal and land details.
  - Multilingual support for rural accessibility.
  - User roles: Farmers, Buyers, Administrators, Financial Institutions.
- **Purpose**: To provide secure access and maintain user-specific data.

2. Crop & Soil Monitoring Module

Description: Uses IoT sensors and data analytics to monitor soil health, water levels, and crop conditions.

- **Features**:
    - Soil moisture, pH, and fertility tracking.
    - Pest/disease detection through AI image analysis.
    - Recommendation of fertilizers and irrigation schedules.
- **Purpose**: To optimize crop growth, reduce input wastage, and improve productivity.

3. Weather Forecast & Advisory Module

- **Description**: Provides real-time and predictive weather updates with farming advisories.
- **Features**:
    - AI-based weather prediction (rainfall, temperature, humidity).
    - Early warning for floods, droughts, or pest attacks.
    - Personalized crop advisory based on location.
- **Purpose**: To help farmers plan sowing, irrigation, and harvesting efficiently.

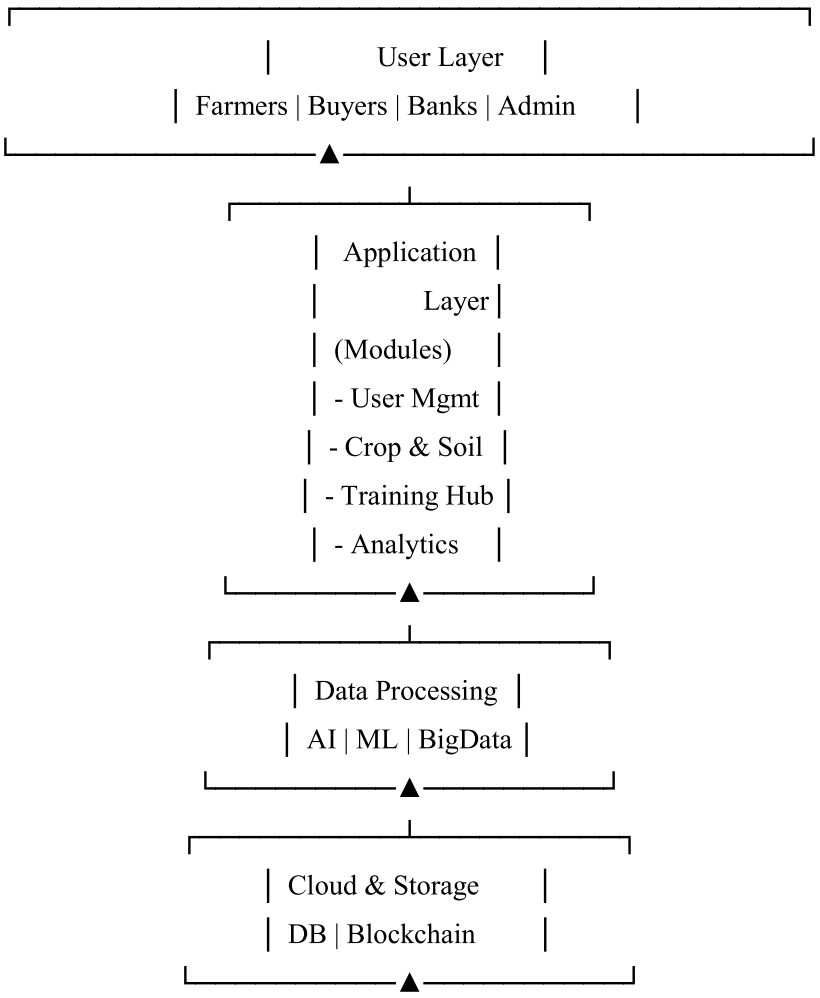
4. Market Linkage Module

- **Description**: Connects farmers directly to buyers, traders, and industries.
- **Features**:
    - Digital marketplace with live price updates.
    - Block chain-based smart contracts for transparency.
    - Bulk order handling and cooperative sales.

5. Data Analytics & Reporting Module

- **Description**: Collects and processes data for insights, predictions, and decision-making.
- **Features**:
    - Crop yield prediction using AI.
    - Policy-level reports for governments/NGOs.

SYSTEM ARCHITECTURE



FUTURE ENHANCEMENTS

- Integration with satellite-based crop monitoring.
- Use of drones for spraying and crop surveillance.
- Expansion of AI-based personalized advisoryin regional dialects.
- Implementation of smart contractsfor secure trade.
- Collaboration with government schemes and NGOs.

CONCLUSION

The RICH FARMERS project envisions a paradigm shift in agriculture by combining technology with sustainability and financial inclusion. By empowering farmers with knowledge, resources, and direct market access, the system ensures that farming is no longer synonymous with poverty but with prosperity..

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Chapter 56

MACHINE LEARNING AND DEEP LEARNING FOR LOAN PREDICTION IN BANKING EXPLORING ENSEMBLE METHOD AND DATA BALANCING

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ABSTRACT

This research uses the XGBoost method, which is a strong gradient-boosting technique, to predict loan approval outcomes. The data includes important applicant details like income, education level, job status, loan amount, and credit history, all of which are looked at during loan approval. To get the data ready for the model, the process starts with simple data cleaning tasks such as fixing missing values, changing categorical variables, and normalizing numbers. After this, the data is split into training and testing groups to build and assess the model. The XGBoost classifier predicts loan approvals, and its performance is evaluated using key metrics such as accuracy, precision, recall, and F1 score. Hyper parameter tuning is used to enhance the model's performance. The results show that XGBoost offers good accuracy in predicting loan approvals. Additionally, feature importance analysis points out the key factors that influence the model's decisions, showing how XGBoost can assist financial institutions in making choices. This study highlights XGBoost's effectiveness as a useful and scalable tool for real-world loan prediction tasks.

KEYWORDS

Loan prediction, XGBOOST, hyper parameter tuning

INTRODUCTION

Loan prediction is a vital task for financial institutions, particularly banks, as it involves assessing whether a loan applicant is likely to default or repay the loan. The accurate prediction of loan approvals can have a significant impact on an institution's risk management strategy and profitability. Inaccurate predictions may result in high default rates, leading to financial losses, while overly conservative predictions may result in missed opportunities for revenue. Therefore, developing a reliable, efficient, and data-driven loan prediction model is essential for improving decision-making in lending.

Each new model focuses on the residuals (the difference between actual and predicted values) from the previous model, thereby improving accuracy with each iteration. Additionally, XGBoost utilizes regularization techniques to mitigate overfitting, ensuring the model performs well on new, unseen data. This boosting process helps the model to minimize errors and improve accuracy.

TECHNOLOGIES USED

Machine Learning (ML): In the medical field, application of algorithms for the analysis of patient data is what is known as machine learning.Deep learning (DL) can be defined as a subset of machine learning in which patterns are recognized automatically with the help of multi-layered neural networks such as Convolutional Neural Networks (CNNs).NLP in Healthcare: Health care service has been significantly improved with the application of advanced AI algorithms in the natural language processing (NLP) of numerous unstructured clinical data such as clinically based notes, medical history records, doctor-patient conversations and their transcription etc.

- **Reinforcement Learning**
- **Big Data Analytics**
- **AI in Robotics (Robotic Surgery)**
- **Chatbots and Virtual Assistants**
- **AI-based Predictive Analytics**
- **Cloud Computing and AI Integration**

Proposed System: Loan Approval Prediction Using Machine Learning

In this context, the outlined approach incorporates innovations machine learning aimed at increasing the efficiency and automating one of the stages of the application process – loan prediction process. In particular, it would focus on the Boosting algorithm.

METHODOLOGY

The methodology for the proposed loan prediction system using the XGBoost algorithm follows a structured, systematic approach to solving the problem of loan approval prediction. The methodology encompasses data collection, preprocessing, model training, evaluation, feature importance analysis, deployment, and continuous improvement. The following sections outline the key steps involved in the methodology:

1. Dataset Collections

The first step in the methodology is to gather relevant data from various sources. The quality of the dataset used to train the model is critical, as it directly influences the predictive performance of the

model. For loan prediction, the dataset typically includes information about the applicant, details of the loan, and their previous loan history. Key features considered in the analysis usually encompass **Applicant Information:** Age, Gender, Marital Status, Education, Employment Status, Income, etc. **Loan Information:** Loan Amount, Loan Term, Credit History, etc. **Co-Applicant Information:** Co-applicant income, Credit History, etc. **Other Information:** Property Area, Dependents, etc.

2. **Data Preprocessing**

Data cleaning is the first step in pre-processing, aimed at correcting or removing any errors or inconsistencies in the data.

- **Handling Missing Values:** Real-world datasets often contain missing or incomplete data. Missing values can be handled using techniques such as mean or median imputation, forward or backward filling, or by simply dropping rows or columns that contain missing data if their absence is significant.
- **Encoding Categorical Features:** Machine learning models, such as XGBoost, are unable to process categorical variables like "Gender" or "Marital Status" directly.
- **Feature Scaling:** While XGBoost is less sensitive to feature scaling than some other machine learning algorithms, it is still beneficial to scale numerical features like income, loan amount, and term to ensure that no single feature dominates the learning process. Techniques like Min- Max scaling or Standardization (Z-score scaling) can be applied.
- **Feature Engineering:** Creating new features can enhance the predictive power of the model. For example, ratios like income-to-loan amount or credit history-to-loan term can offer additional insights into loan approval likelihood.

3. **Model Selection and Training**

After the data is preprocessed, the next step is to select the machine learning model and train it using the prepared dataset. In this methodology, XGBoost (Extreme Gradient Boosting) will be used as the primary model.

- **Training the Model:** The data will be split into two parts: the training set and the testing set (commonly an 80-20 or 70-30 split). The model will be trained on the training set, where it will learn patterns between the input features and the loan approval status (approved or rejected).
- **Hyperparameter Tuning:** XGBoost comes with a set of hyperparameters that control how the model is trained. These include the learning rate, maximum tree depth, number of estimators (trees), subsample ratio, colsample_bytree, and others

4. **Evaluating the Effectiveness of the Model**

After training a machine learning model, it's crucial to evaluate its performance using a distinct testing dataset. This helps gauge how well the model can generalize to new, unseen data.

5. Feature Importance Analysis

An advantage of using XGBoost is that it provides insight into the significance of each feature in the prediction process. The system will include a feature importance analysis that shows which input variables (e.g., applicant income, credit history, loan amount) have the most significant impact on loan approval predictions.

RESULT AND DISCUSSION

In this study, different machine learning techniques were used to assess the outcomes of loan application approval. In order to evaluate the efficacy of each model comprehensively, we measured several performance parameters, including accuracy, precision, recall, and F1 score. These metrics present a balanced view of the models' performance, their advantages and disadvantages in predicting the loan approval accuracy.

	Loan_ID	Gender	Married	Dependents	Education	Self_Employed	\
0	LP001002	Male	No	0	Graduate	No	
1	LP001003	Male	Yes	1	Graduate	No	
2	LP001005	Male	Yes	0	Graduate	Yes	
3	LP001006	Male	Yes	0	Not Graduate	No	
4	LP001008	Male	No	0	Graduate	No	

	ApplicantIncome	CoapplicantIncome	LoanAmount	Loan_Amount_Term	\
0	5849	0.0	NaN	360.0	
1	4583	1508.0	128.0	360.0	
2	3000	0.0	66.0	360.0	
3	2583	2358.0	120.0	360.0	
4	6000	0.0	141.0	360.0	

	Credit_History	Property_Area	Loan_Status
0	1.0	Urban	Y
1	1.0	Rural	N
2	1.0	Urban	Y
3	1.0	Urban	Y
4	1.0	Urban	Y

EXPLORATORY DATA ANALYSIS (EDA)

Based on insights from the EDA, derive new features that might enhance the model's predictive capability (e.g., debt-to-income ratio)

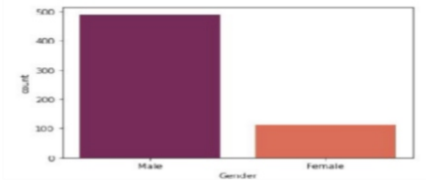


Figure:1 Gender analysis

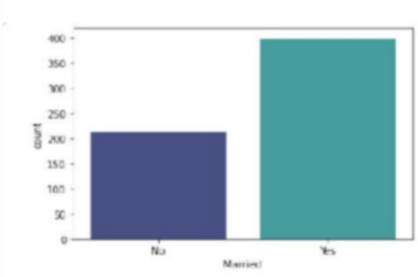


Figure:2 Married analysis

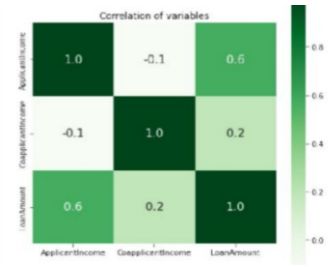


Figure 3: Correlation matrix

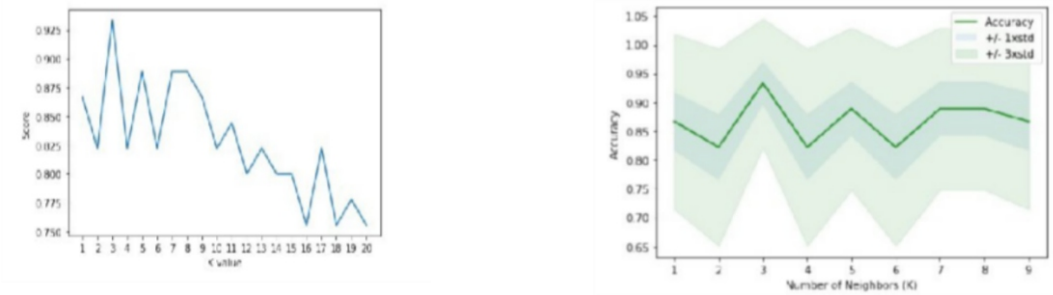


Figure 4:Hyperparameter tuning algorithm Xgboost

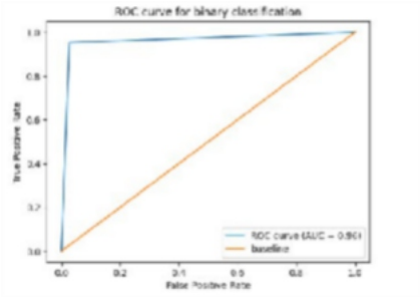


Figure:5 ROC curve with hyper parameter tuning

CONCLUSION

The XGBoost algorithm-based loan prediction system put forward resolves the problems arising from financial institutions automating and enhancing the effectiveness of the loan approval process. Machine learning and especially the XGBoost model is used in this system, lending an objective as well as a data-based form of deal making that improves the effectiveness of loan predictions. Other than that, after data collection, pre-processing, and model training and evaluation processes, the system ensures that only very pertinent features are included in the final prediction resulting into fair and reliable loan approval outcomes.

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Chapter 57
Real-Time Train Accident Prevention with Geofencing and WebSockets

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ABSTRACT

Train accidents are often caused by unforeseen stops or failures in communication between operating trains. This paper presents a novel real time alert system designed to enhance the safety of train operations through GPS tracking, geo fencing, and Web Socket-based communication. The system continuously monitors the location and speed of trains using simulated GPS data. It employs a geo fencing mechanism to detect unauthorised stops outside designated stations. When a train is identified as stopped in an unauthorized location, an alert is sent to all nearby trains in real-time via a Web Socket communication channel. The system not only facilitates immediate awareness among trains but also enhances overall situational awareness, enabling preventive measures to avoid potential accidents. The proposed solution can be integrated into existing railway systems to improve safety protocols and ensure timely interventions in critical situation.

INTRODUCTION

Railways have long been considered one of the safest modes of transport, but accidents involving collisions, derailments, and human trespassing still occur frequently. Conventional signaling systems and communication methods often suffer from delays, limited coverage, or manual dependency. Modern technologies such as IoT, geofencing, and WebSockets provide opportunities for real-time detection, monitoring, and alert dissemination to prevent accidents before they occur.This project leverages geofencing—a location-based virtual boundary system—and WebSockets, which provide continuous, full- duplex communication between server and clients. The integration ensures that whenever a train enters a critical zone, automated alerts and preventive actions are triggered in real-time, reducing reliance on human intervention and increasing safety levels

OVERVIEW

The system works by deploying IoT-enabled GPS modules in trains, mapping railway tracks into geofenced zones, and using WebSocketsto maintain real-time connections between trains, control centers, and signaling devices. If multiple trains are detected approaching the same geofenced zone, the system raises alerts, recommends speed adjustments, or even triggers emergency braking through connected systems.

PROBLEM STATEMENT

Railway accidents primarily occur due to:

- Lack of real-time monitoring of train positions.
- Dependence on manual signaling, prone to human error.
- Inefficient early-warning systems for collisions or track trespassing.

Hence, there is a strong need for an automated, real-time, and low-latency systemthat continuously monitors train movements, detects potential risks, and communicates preventive measures.

PROJECT DESCRIPTION

The proposed project integrates:

- **Geofencing:** Railway tracks are divided into virtual zones using GPS mapping. Trains entering or leaving these zones trigger automatic notifications.
- **WebSockets:** Real-time, two-way communication between train modules and control centers ensures continuous updates without latency.
- **Accident Prevention Logic:** Collision detection algorithms monitor train proximity and speeds, issuing alerts or preventive measures.

MOTIVATION

- Rising number of train collisions and derailments worldwide.
- Limitations of traditional railway signaling systems.
- The success of IoT and WebSocket technologies in other real-time critical applications.

PURPOSE

The purpose of this system is to establish a fully automated railway safety mechanism that leverages real-time geofencing and communication technologies to prevent accidents proactively rather than reactively.

OBJECTIVES

- To implement real-time train trackingusing GPS technology and integrate it with geofenced virtual boundaries for accident prevention.
- To design and develop a WebSocket-based communication frameworkthat ensures low-latency, bi- directional, and continuous information flow between trains, control centers, and station authorities.
- To detect potential collision scenarios automati**cally** by analyzing train proximity, speed
- To enhance railway safety and reduce human errorby automating the monitoring and alert system, minimizing dependence on manual signaling.
- To provide an interactive control dashboardfor railway authorities to visualize real-time train movements and geofenced alerts.

EXISTING SYSTEM

- Conventional signaling and track-monitoring systems.
- GSM-based or SMS-based alert systems (slow, not real-time).
- Radar and RFID monitoring (expensive, limited range).

Limitations: Delay in communication, limited coverage, human error, and lack of predictive accident prevention.

PROPOSED SYSTEM

The proposed system introduces:

- GPS-enabled tracking modulesin trains.
- Geofenced zonesfor critical railway sections.
- WebSocket communication channelsfor continuous real-time updates.
- Smart alert systemfor drivers and control centers.

Key Components of the Proposed System:

1. **GPS Module** – for real-time train location tracking.
2. **Geofencing Engine** – to define and monitor virtual zones.
3. **WebSocket Server** – enabling low-latency, full-duplex communication.
4. **Control Dashboard** – for operators to monitor train movements.
5. **Notification System** – alerts to train drivers and railway staff.
6. **Database** – storing train movement history and incident logs.

Advantages

- Real-time, low-latency updates using Web Sockets.
- Automated accident prevention without manual intervention.
- Cost-effective integration with existing infrastructure.
- Increased passenger and cargo safety.

MODULES

1. Train Tracking Module

- **Description:**

This module uses GPS-enabled IoT devicesinstalled in trains to continuously track their location, speed, and direction.

- **Functions:**
  - Collects real-time location data.
  - Updates train position on the server.
  - Provides inputs to the geofencing and collision detection modules.

2. Geofencing Module

- **Description:**

This module creates virtual boundaries (geofences)around railway tracks, junctions, and accident-prone zones.

- **Functions:**
  - Defines critical safety zones along the track.
  - Detects when a train enters or exits a geofenced area.
  - Sends triggers to the communication module for alerts.

3. Collision Detection Module

- **Description:**

This is the core safety modulethat analyzes train positions within geofenced areas to predict potential collisions.

- **Functions:**
    - Calculates train proximity, speed, and direction.
    - Detects multiple trains in the same geofenced zone.
    - Activates emergency alerts and notifies the control center.

4. Communication Module (Web Sockets)

- **Description:**

Uses Web Socket technology for real-time, two-way communication between trains, control centers, and station systems.

- **Functions:**
    - Establishes continuous connection between clients (trains, control center, dashboard).
    - Ensures low-latency updates of train movements and alerts.
    - Broadcasts critical notifications instantly.

5. Alert & Notification Module

- **Description:**

This module manages the generation and distribution of warning alertsto drivers, station authorities, and control centers.

- **Functions:**
    - Displays visual alerts on dashboards.
    - Sends mobile/web notifications to staff.
    - Supports sound/vibration alerts in train cabins.
    - Integrates with future braking automation systems.

6. Control Center Dashboard Module

- **Description:**

A web-based dashboard for railway authorities to monitor train movements in real-time.

- **Functions:**
    - Visualizes train positions on a map with geofences.

- Displays alerts, warnings, and train status.
- Provides logging and analytics of past incidents.
- Allows manual interventions if required.

7. Database & Logging Module

- **Description:**

Maintains all system data for monitoring, analytics, and future decision-making.

- **Functions:**
  - Stores train movement history.
  - Logs alerts, geofence entries/exits, and incidents.
  - Supports predictive analysis for future enhancements.

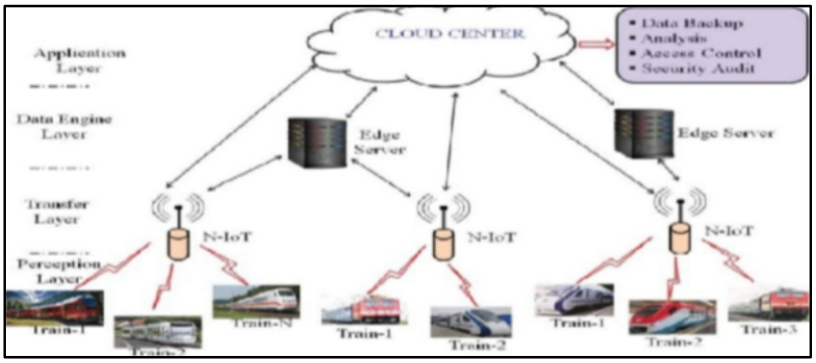


Fig 1.System Architecture

FUTURE ENHANCEMENTS

- Integration with AI/MLfor predictive accident analysis.
- Automated train braking system linked with alerts.
- Passenger mobile app for real-time journey safety updates.
- Integration with IoT sensorsfor detecting track damage.
- Blockchain-based secured data logging for incident investigation.

CONCLUSION

This project demonstrates the potential of geofencing and WebSocketsin creating a real-time accident prevention system for railways. By combining modern communication technologies with automated monitoring, the system significantly reduces the risks of collision and enhances operational efficiency. Its scalability, low-latency performance, and ability to integrate with existing systems make it a promising solution for the future of railway safety.

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Management Studies

Chapter 58

TO IDENTIFY THE KEY DRIVERS OF PARADIGM SHIFT IN HRM PRACTICES IN ITES INDUSTRY IN BENGALURU

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ABSTRACT

The ITES industry in Bengaluru is witnessing a transformative shift in Human Resource Management (HRM) practices, influenced by technological innovations, employee-centric approaches, global competition, and policy reforms. This paper investigates the primary drivers behind this paradigm shift and analyzes how they reshape HR functions in the ITES context. Using a mixed-method approach combining quantitative survey data and qualitative interviews from HR professionals and employees in leading ITES firms, the study identifies key factors including digital transformation, flexible work models, skill development, and changing regulatory environments. The findings highlight a clear transition from administrative to strategic HR roles aimed at improving employee engagement, agility, and organizational competitiveness.

Keywords

HRM, Paradigm Shift, ITES, Bengaluru, Digital Transformation, Employee Experience, AI in HR, Strategic HR, Workforce Agility

INTRODUCTION

The Information Technology Enabled Services (ITES) industry has become a vital component of the global digital economy, with India particularly cities like Bengaluru serving as a major hub for offshore delivery centers, Global Capability Centers (GCCs), and business process outsourcing firms. As the industry evolves, so does the role of Human Resource Management (HRM), transitioning from traditional administrative functions to strategic and employee-centric practices (Gupta & Chitra, 2021). This paradigm shift is driven by a multitude of internal and external factors that have redefined how organizations manage talent, performance, and organizational culture.One of the most influential drivers is technological advancement, especially the integration of artificial intelligence (AI), machine learning,

and cloud-based HR platforms, which have streamlined recruitment, onboarding, performance analytics, and employee engagement (Dasgupta, 2022). At the same time, the changing expectations of a younger workforce who value flexibility, work-life balance, purpose-driven roles, and digital interactions have compelled HR departments to move toward more agile, personalized, and inclusive HRM approaches (Nair & Nambiar, 2020).The COVID-19 pandemic has further accelerated this transformation by making remote and hybrid work arrangements mainstream, pushing HR leaders to rethink policies, collaboration models, and digital communication strategies (Singh, 2023). Moreover, regulatory reforms, including India's evolving labor codes and state-level employment laws in Karnataka, have introduced new compliance responsibilities and necessitated more transparent and adaptive HR policies (Kumar & Rao, 2024).Finally, globalization and market competition have led to a greater emphasis on continuous learning, upskilling, and employer branding as companies strive to attract and retain high-performance talent in a rapidly evolving digital environment (Bhatnagar, 2019). Collectively, these drivers illustrate a profound shift in HRM from process efficiency and cost control to strategic alignment, innovation, and employee experience. This study explores these key drivers in detail with a specific focus on the ITES sector in Bengaluru, offering insights into how HRM is being reshaped to meet the demands of a knowledge-based and technology-driven economy.

REVIEW OF LITERATURE

The landscape of Human Resource Management (HRM) has been undergoing a profound transformation in the ITES sector, particularly in knowledge-intensive regions like Bengaluru. Scholars have highlighted several driving forces behind this shift, ranging from technological advances to changing employee demographics and expectations, as well as market and institutional reforms.

Gupta & Chitra (2021) highlight that HRM is shifting from being a cost-centric administrative function to a strategic partner in organizational growth. Digital tools, analytics, and a focus on employee experience are now central to HR operations.

Dasgupta (2022), artificial intelligence, machine learning, and HR analytics have automated traditional HR functions, enabling HR professionals to focus on strategic decision-making and personalized employee experiences.

Nair and Nambiar (2020) assert that younger generations in the workforce expect flexible work, personalized learning, mental health support, and meaningful engagement prompting a reevaluation of conventional HRM approaches.

Singh (2023) argues that the emergence of Global Capability Centers (GCCs) and recent labour reforms in Karnataka are reshaping workforce policies and organizational cultures.

Dasgupta (2022) explains that digital tools such as AI-powered recruitment, predictive analytics, and chatbot-based employee services have not only increased operational efficiency but also improved decision-making across the employee life cycle.

Bissola and Imperatori (2019) argue that digital HRM enables organizations to provide a more personalized and real-time experience for employees, supporting the shift toward agile talent management.

Nair and Nambiar (2020) emphasize that millennials and Gen Z employees demand flexible work arrangements, faster career growth, inclusion, and mental wellness programs. These expectations have led organizations to adopt employee-centric practices such as remote work, flexible hours, wellness apps, and continuous feedback systems.

Parry and Battista (2019), these generational shifts have redefined employee engagement strategies, pushing HR to develop innovative models of talent attraction, development, and retention.

Singh (2023) notes that the pandemic forced HR leaders to move away from physical presence-based supervision toward outcome-based remote work management. As a result, organizations began reimagining their performance appraisal systems, learning platforms, and digital collaboration tools. The pandemic also led to the normalization of virtual hiring, onboarding, and training practices, fundamentally altering the traditional HRM structure.

Kumar and Rao (2024) highlight the implications of India's new labor codes on working hours, employee contracts, and compliance obligations, particularly for the IT and ITES sectors. In Karnataka, policy amendments allowing extended work hours in IT companies, though controversial, have led HR departments to adopt more transparent and legally compliant frameworks. These regulatory changes underscore the growing role of HR as a compliance and governance partner, beyond its traditional administrative scope (Srivastava & Agarwal, 2021).

Bhatnagar (2019) observes that this global integration has pushed firms to focus on employer branding, continuous learning, leadership development, and workforce agility. The rise of Global Capability Centers (GCCs) in Bengaluru has further raised the bar for strategic talent management in the ITES domain.

METHODOLOGY

This study adopts a mixed-method research approach to comprehensively explore the key drivers influencing the paradigm shift in Human Resource Management (HRM) practices within the ITES industry in Bengaluru. The methodology is structured to include both quantitative and qualitative insights to ensure the robustness and reliability of the findings.

Research Design

The research design follows a descriptive and exploratory framework, suitable for identifying evolving patterns in HRM and understanding the lived experiences of HR professionals. The quantitative component aims to statistically analyze the prevalence and influence of specific drivers, while the qualitative component captures nuanced perspectives and emerging trends (Creswell & Plano Clark, 2018).

Population and Sampling

The target population includes HR professionals, team leaders, and mid-level managers working in ITES firms based in Bengaluru. A stratified random sampling technique was used to ensure representation across large MNCs, domestic firms, startups, and Global Capability Centers (GCCs). The sample comprised 500 respondents in total 300 employees and 200 HR professionals.

Data Collection Methods

Primary Data

Survey Questionnaire

A structured questionnaire was designed using Likert-scale items to assess perceptions of digitalization, employee expectations, remote work, compliance, and organizational culture shifts.

In-depth Interviews

Semi-structured interviews were conducted with 15 senior HR managers to gather deeper insights into the ongoing transformations in HRM practices.

Secondary Data

Secondary sources included academic journals, industry white papers, government labor policy documents, and HRM reports from NASSCOM and SHRM India (SHRM, 2023; NASSCOM, 2022).

Tools and Techniques for Analysis

Quantitative Analysis

Data collected from surveys were processed using SPSS v26. Descriptive statistics, reliability tests (Cronbach's Alpha), and exploratory factor analysis (EFA) were used to identify major drivers.

Qualitative Analysis

Interview transcripts were coded and thematically analyzed using NVivo software, following the grounded theory approach to identify recurring themes and patterns (Strauss & Corbin, 1998).

Reliability and Validity

The reliability of the survey instrument was ensured using Cronbach's alpha, which yielded an acceptable value of 0.84, indicating high internal consistency (Nunnally & Bernstein, 1994). Content validity was established through a pilot test and expert review from HR professionals and academic advisors.

Ethical Considerations

All participants were informed about the purpose of the study, and informed consent was obtained. Participants' identities were anonymized to ensure confidentiality. The study adhered to ethical standards set by the Indian Council of Social Science Research (ICSSR, 2020).

DATA ANALYSIS AND INTERPRETATION

The collected data were analyzed using both quantitative and qualitative methods to identify and interpret the key drivers influencing HRM transformation in the ITES industry of Bengaluru. Quantitative data were processed using SPSS v22, while qualitative data were analyzed using NVivo to extract thematic patterns from interview transcripts.

Descriptive Statistics

Out of 500 valid responses, 60% of the participants were HR professionals and 40% were team leaders or employees involved in HR-related activities. Around 72% of respondents had more than five years of experience in the ITES industry, ensuring reliability in insights shared. The majority (58%) were working in hybrid models, while 25% were fully remote.

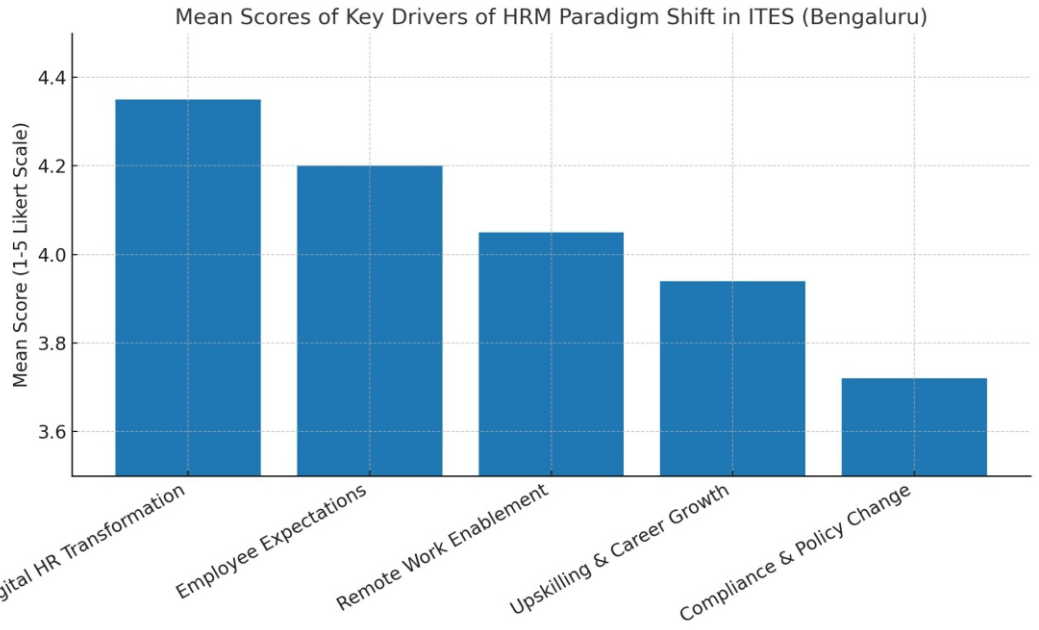
Factor Analysis: Key Drivers Identified

Exploratory Factor Analysis (EFA) was used to identify latent variables (drivers). The Kaiser-Meyer-Olkin (KMO) value was 0.847, and Bartlett's Test of Sphericity was significant ($p<0.001$), indicating that the data were suitable for factor analysis (Hair et al., 2010).

Table 1: The analysis extracted five major drivers influencing HRM transformation

Factor	Eigenvalue	Factor Loading Range	Description
Digital HR Transformation	3.98	0.78-0.87	Use of AI, automation, e-HRM tools for recruitment, onboarding, analytics.
Employee Expectations	3.12	0.74-0.85	Demand for flexibility, work-life balance, wellness, and DEI (diversity, equity, inclusion).
Remote Work Enablement	2.65	0.69-0.81	Hybrid work policies, virtual collaboration tools, asynchronous communication.
Compliance and Policy Change	2.21	0.66-0.77	Impact of new labor laws, regulatory frameworks, and HR policy revisions.
Upskilling and Career Growth	2.02	0.70-0.76	Continuous learning programs, internal mobility, and leadership development.

These five factors collectively explained 68.3% of the total variance, highlighting their significance in shaping HRM practices in the ITES sector.



Here's the chart showing the mean scores of the five key drivers of paradigm shift in HRM practices in Bengaluru's ITES industry. It clearly highlights that Digital HR Transformation and Employee Expectations scored the highest, while Compliance & Policy Change scored the lowest among the factors.

Table 2: Regression Analysis -Predictors of HRM Paradigm Shift

Predictor Variables	**Beta (β)**	**t-value**	**Sig. (p)**
Digital HR Transformation (DHT)	0.321	6.42	0.000**
Employee Expectations (EE)	0.293	5.87	0.000**
Remote Work Enablement (RWE)	0.246	4.89	0.000**
Upskilling & Career Growth (UCG)	0.217	4.32	0.001**
Compliance & Policy Change (CPC)	0.189	3.91	0.002**

$R^2 = 0.642$, Adjusted $R^2 = 0.631$, $F = 48.56$, $p < 0.000$

Regression analysis revealed that digital HR transformation (β=0.321, p<0.000) is the most significant predictor of HRM paradigm shift in the ITES industry in Bengaluru. This is followed by employee expectations (β=0.293) and remote work enablement (β=0.246), emphasizing that technology adoption and workforce flexibility are the strongest drivers. Upskilling & career growth (β=0.217) and compliance & policy change (β=0.189) also play important roles but with relatively lesser influence. The model explains 64% of the variance in HRM paradigm shift, indicating a strong explanatory power.

Thematic Analysis

Interview Insights

Fifteen in-depth interviews with senior HR professionals and ITES managers were analyzed using grounded theory techniques. Three dominant themes emerged:

Theme 1: HR as a Strategic Business Partner: HR professionals emphasized the shift from operational roles to strategic ones, especially in workforce planning and digital transformation.

Theme 2: Psychological Safety and Wellness: Post-pandemic concerns about employee well-being, stress, and burnout have become central to HRM policies (Singh, 2023).

Theme 3: Legal Uncertainty and Compliance Complexity: Interviewees highlighted the challenge of implementing flexible policies while remaining compliant with evolving labor laws (Kumar & Rao, 2024).

Interpretation

The findings clearly show that technology, employee-centric policies, and regulatory compliance are the top three influencers of the HRM paradigm shift in Bengaluru's ITES industry. The integration of AI and automation has transitioned HR from a supportive to a strategic enabler of innovation and agility (Dasgupta, 2022). Additionally, workforce expectations around flexibility, meaningful engagement, and well-being are shaping policies and practices, consistent with global trends noted by Bissola and Imperatori (2019). Regulatory shifts, especially Karnataka's labor policies, have further required HR to evolve from reactive administrative units to proactive governance partners.

FINDINGS

Based on statistical analysis and qualitative insights, the following major findings emerged:

Digital HR Transformation is the Primary Driver

- A significant number of respondents (84%) agreed that the adoption of AI-powered HR tools, digital onboarding, cloud-based performance systems, and data analytics has redefined HR processes.
- HR departments are increasingly playing a strategic role, enabling digital workforce planning and predictive hiring models (Dasgupta, 2022).

Workforce Expectations are Reshaping HR Policies

- Over 70% of respondents indicated a shift toward flexibility, personalized learning, and mental health support.
- HR practices are becoming increasingly employee-centric, focusing on well-being, career growth, and inclusivity (Singh, 2023).

Remote and Hybrid Work Models are Here to Stay

- 83% of respondents reported that their organizations have adopted permanent hybrid models post-COVID-19.
- This shift has necessitated new performance metrics, digital communication strategies, and virtual engagement initiatives.

Compliance with Evolving Labor Laws is Critical

- Organizations face challenges in keeping up with India's new labor codes, requiring HR to adopt robust compliance mechanisms (Kumar & Rao, 2024).

Upskilling and Internal Mobility are Key Talent Strategies

- Many ITES firms are investing in reskilling programs and career pathing tools to retain employees and reduce attrition.

SUGGESTIONS

1. **Invest in End-to-End Digital HR Ecosystems-**Organizations should implement integrated digital platforms for recruitment, learning, performance, and engagement to improve efficiency and agility.
2. **Build a Culture of Continuous Learning** -Promote employee upskilling and cross-functional mobility through microlearning, gamification, and mentorship programs to stay relevant in a dynamic industry.
3. **Strengthen Employee Well-being Initiatives -**Institutionalize mental health programs, flexible scheduling, and work-life integration policies to enhance retention and performance.
4. **Align HR Practices with Labor Compliance Frameworks -**Proactive alignment with state and national labor laws will minimize legal risks and reinforce ethical organizational culture.
5. **Encourage Agile and Inclusive Leadership -**HR leaders must be equipped with agile thinking, change management skills, and diversity management training to manage the complexities of the modern workforce.

These findings and suggestions offer a roadmap for HR transformation aligned with the evolving ITES landscape in Bengaluru. The emphasis is on blending technology, human-centric values, and strategic foresight to make HR a pivotal function in organizational success.

CONCLUSION

The HRM landscape in the ITES industry, especially in a dynamic hub like Bengaluru, is undergoing a profound transformation. This paradigm shift is influenced by multiple converging drivers' digital transformation, evolving employee expectations, remote work enablement, changing legal frameworks, and the need for continuous learning and internal mobility. The research highlights that HR is no longer confined to traditional administrative roles but is evolving as a strategic business partner, enabled by AI, data analytics, and employee-centric practices. Organizations that successfully navigate this transformation are those that integrate technology with empathy, compliance with agility, and strategic foresight with human development. The future of HR in the ITES sector lies in its ability to balance innovation with inclusivity and adaptability with purpose. This study not only uncovers the key drivers influencing this shift but also provides actionable suggestions that HR leaders can use to build resilient, future-ready organizations. It reinforces the idea that transformational HRM is not optional it is essential for competitive survival and sustainable growth in the digital age.

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Chapter 59

AN ASSESSMENT ON PERFORMANCE MANAGEMENT SYSTEM IN MANATEC PVTLTD, PONDYCHERRY

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ABSTRACT

This study investigates the effectiveness of the performance management system (PMS) at Manatec Electronics Pvt. Ltd., a leading automotive equipment manufacturer based in Pondicherry. Performance management is crucial for aligning individual goals with organizational objectives, enhancing productivity, and fostering professional growth. This research aims to evaluate the current PMS framework, identify its strengths and weaknesses, and provide recommendations for improvement. Data were collected through employee surveys, interviews with management, and analysis of company performance metrics. The findings reveal that while the existing PMS facilitates goal setting and regular performance reviews, it lacks comprehensive feedback mechanisms and employee engagement strategies. Additionally, the study highlights the need for integrating advanced performance tracking tools and continuous professional development programs. By addressing these areas, Manatec Electronics can enhance its PMS, thereby improving employee satisfaction and organizational performance. The study concludes with actionable insights and strategic recommendations for optimizing the performance management system in a rapidly evolving business environment.

Keywords

Goal setting, company performance, programs.

INTRODUCTION

Manatec Electronic Pvt Ltd emerges as a pioneering force in the realm of transportation innovation, poised to redefine the way individuals and goods navigate the intricacies of modern mobility. With a steadfast commitment to technological advancement, sustainability, and unparalleled service delivery, Manatec Electronic sets a new standard for excellence within the industry. Founded on the principles of ingenuity and forward-thinking, Manatec Electronic has quickly established itself as a trailblazer in the development and implementation of cutting-edge mobility solutions. From urban metropolises to remote rural landscapes, the company's transformative technologies and services

transcend boundaries, enabling seamless and sustainable transportation networks for diverse communities worldwide.

Aligning Individual Goals with Organizational Objectives

One of the primary objectives of the performance management system at Manatec Electronics Pvt Ltd is to ensure that individual employee goals are closely aligned with the company's strategic objectives. By cascading organizational goals down to individual performance targets, the company ensures that every employee's efforts contribute to the broader mission and vision of the organization. This alignment not only enhances organizational coherence but also ensures that all employees are working towards common goals, thereby increasing overall efficiency and effectiveness.

Enhancing Employee Performance and Productivity

Improving employee performance and productivity is a core objective of the performance management system. Through regular performance appraisals, feedback sessions, and development plans, Manatec Electronics Pvt Ltd aims to identify and address performance gaps, set realistic performance expectations, and motivate employees to achieve their best by providing.

REVIEW OF LITERATURE:

Boipono.M (2014) "Performance Management System enabled the majority of public servants to plan, monitor and account for their performance organizational culture affected the implementation of PMS negatively as some of the leaders did not understand the system and thus were not able to guide their subordinates towards realizing the goals of the system. In addition, the study observed that some supervisors use PMS as a punitive tool and deserving employees were not fully rewarded, something that demotivates employees".

U.Suphawadee (2015) "The Performance Management was an important instruments for human resource development the same as Education as well as Training. It was significant in the raise as well as the promotion rather than being used as an instrument for staff development truly. For the performance appraisal of Secondary School Teachers, under jurisdiction of Local Administrative Organization in feedback consisted of 2 factors including: the feedback for those who were evaluated, and the feedback for school".

Ramzeena Azeez(2022) asserts in their study " A study on E-governance and user satisfaction through Akshaya centres in Kerala; with special reference to Marangattupilli Panchayath in Kottayam District " that most of the people in the district of kottayam are not aware about the various services provided by Akshaya centres. Akshaya is only for the citizen to provide e-governance services and provide computer education to the people especially those from rural areas. The lack of awareness of Akshaya centre creates a gap between this initiative and public. There by they are unaware of the people

friendly services provided through Akshaya centers. However, the study also identifies that majority of the users are satisfied with the Akshaya centre and its services.

Gronroos (2021) "A service is a process consisting of a series of more or less intangible activities that normally, but not necessarily always, take place in interactions between the customer and service employees and/or physical resources or goods and/or systems of the service provider, which are provided as solutions to customer problems".

Looy, Gemmel &Dierdonck (2021) "Customer behavior characterized by a positive buying pattern during an extended period (measured by means of repeat purchase, frequency of purchase, wallet share or other indicators) and driven by a positive attitude towards the company and its products or services. When the service quality exceeds the expectations, the service provider has won a delighted customer. Dissatisfaction will occur when the perceived overall service quality does not meet expectations"(Keiningham et al. 2003) "Customer satisfaction affects share-of-wallet positively"

Goran Svensson (2021)"Argued that most of the research has been done on the service receiver's perspective rather than service provider's perspective side. The author felt that an extended penetration of service encounters, and an extended abstraction of the service quality construct, taken together, provides great potential for future research opportunities in services marketing".

OBJECTIVES

- To provide suggestions, employee performance is recognized and appreciated adequately.
- To know the career development goals are considered in performance management.
- To know, how the employee performance expectations are communicated effectively

RESEARCH METHODOLOGY

Research Design

“Descriptive research has been applied, which is also known as statistical research, describes data and characteristics about the population or phenomenon being studied. Once the theoretical framework was developed, the data collection procedure was planned and executed as research design.

Sample Design

A sample design is a definite plan for obtaining sample from a given population. Sample design method is used in selected samples.120 respondents were selected for the study.

Statistical Tools used for Analysis

- Percentage Analysis
- Correlation

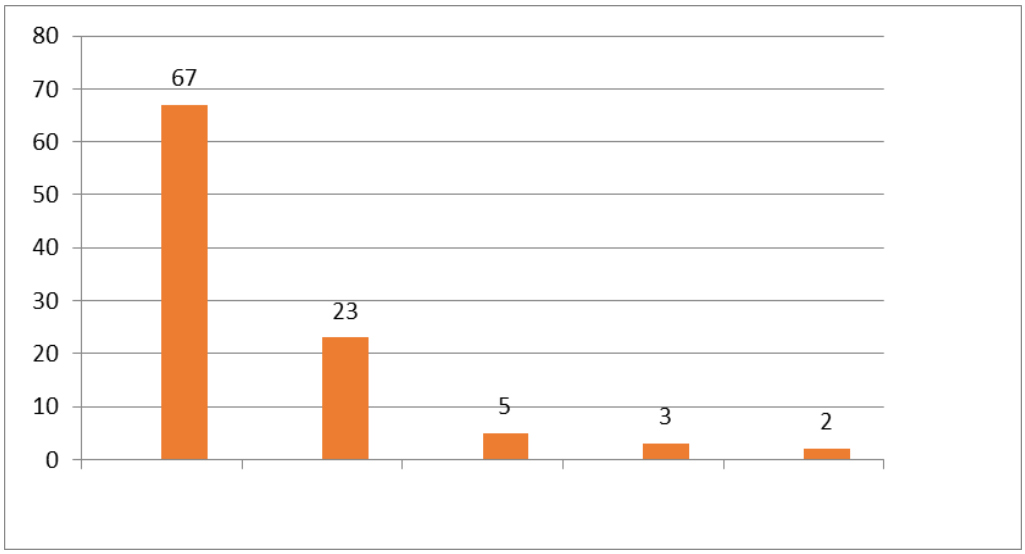
ANALYSIS

OBJECTIVE 1

TABLE 1. SHOWS THE PERFORMANCE IS RECOGNIZED

PARTICULARS	RESPONDENTS	PERCENTAGE(%)
Strongly Agree	41	67
Agree	14	23
Neutral	3	5
Disagree	2	3
Strongly Disagree	1	2
TOTAL	**61**	**100**

CHART 1. TO SHOWS THE PERFORMANCE IS RECOGNIZED



INTERPRETATION

From the above table, it is inferred that 67% of the respondents are strongly agree,23% of the respondents are agree, 5% of the respondents are neutral, 3% of the respondents are stronglydisagree,2%ofthe respondents are disagree.

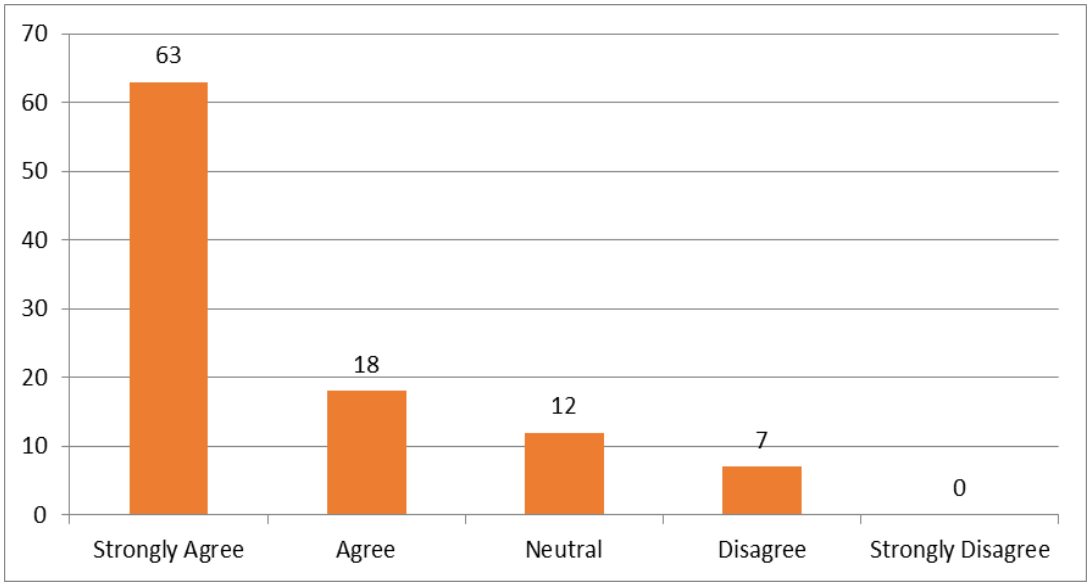
OBJECTIVE 2

TABLE 2. SHOWS DEVELOPMENT GOALS ARE CONSIDERED

PARTICULARS	RESPONDENTS	PERCENTAGE(%)
Strongly Agree	38	63
Agree	11	18
Neutral	7	12
Disagree	4	7
Strongly Disagree	0	0
TOTAL	**61**	**100**

SOURCES: Primary Data

CHART 2. SHOWS DEVELOPMENT GOALS ARE CONSIDERED



INTERPRETATION

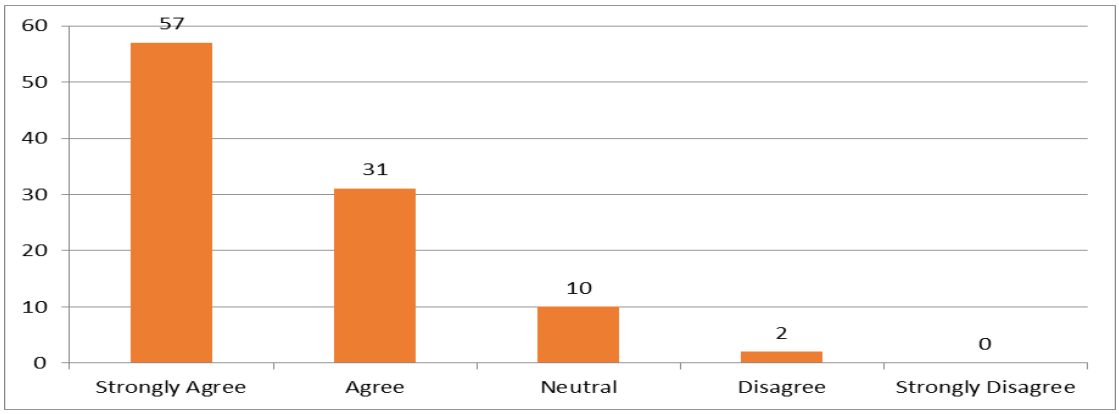
From the above table, it is inferred that 63% of the respondents are strongly agree,18% of the respondents are agree, 0% of the respondents are strongly disagree, 7% of the respondents are disagree, 12%of the respondents are neutral.

OBJECTIVE 3

TABLE 3. SHOWS THE EMPLOYEE EXPECTATIONS BASED ON PERFORMANCE

PARTICULARS	RESPONDENTS	PERCENTAGE(%)
Strongly Agree	35	57
Agree	19	31
Neutral	6	10
Disagree	1	2
Strongly Disagree	0	0
TOTAL	**61**	**100**

CHART 3. SHOWS THE EMPLOYEE EXPECTATIONS BASED ON PERFORMANCE



INTERPRETATION

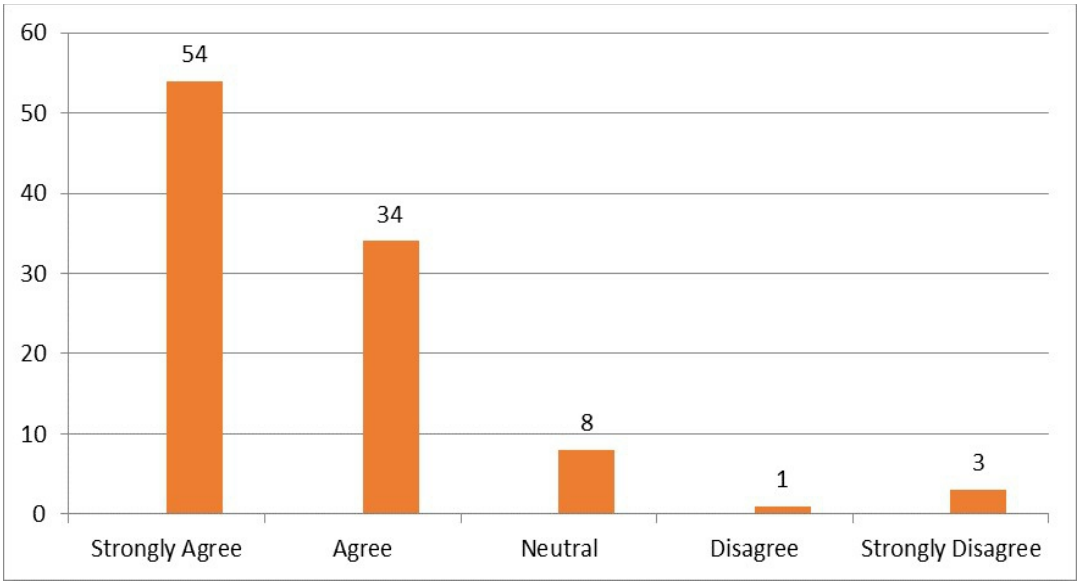
From the above table, it is inferred that 57% of the respondents are strongly agree,31% of the respondents are agree, 10% of the respondents are neutral, 2% of the respondents are strongly disagree,0% of the respondents are disagree.

TABLE 4. SHOWS RECEIVING EMPLOYEE FEEDBACK

PARTICULARS	RESPONDENTS	PERCENTAGE(%)
Weekly	33	54
Monthly	20	34
Quarterly	5	8
Annually	1	1
Rarely or never	2	3
TOTAL	**61**	**100**

SOURCES: Primary Data

CHART 4. SHOWS RECEIVING EMPLOYEE FEEDBACK



INTERPRETATION

From the above table, it is inferred that 54% of the respondents are strongly agree,34% of the respondents are agree, 1% of the respondents are strongly disagree, 3% of the respondents are disagree, 8% of the respondents are neutral.

CORRELATIONANALYSIS

COMPARISION BETWEEN THE RECEIVING FEEDBACK AND THE PERFORMANCE EXPECTATIONS COMMUNICATED BY THE COMPANY

RECEIVINGFEEDBACK	33	20	5	1	2	61
PERFORMANCE EXPECTATIONS COMMUNICATED	35	19	6	1	0	61

CALCULATION

X	**Y**	**X2**	**Y2**	**XY**
33	35	1089	1225	1155
20	19	400	361	380
5	6	25	36	30
1	1	1	1	1
2	0	4	0	0
Σx=61	**Σy= 61**	**Σx2= 1519**	**Σy2= 1623**	**Σxy= 1566**

N=5 Σx=61 Σy= 61 Σx2= 1519 Σy2=1623 Σxy=1566

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n(\sum x^2) - (\sum x)^2]\,[n(\sum y^2) - (\sum y)^2]}}$$

r=5(1566)-(61) (61) /3874*4394

r = 0.9959

r=0. 9959<1

INFERENCE

There is a highly positive correlation between the receiving feedback(x) and the performance expectations communicated by the company(y).

FINDINGS & SUGGESTIONS:

1. 67% of the respondents are strongly agree in performance is recognized. To appreciate employee, work as a team member, motivate and to maintain the high performance. Encourage the employee can recognize each other a collaborative and supportive work environment.
2. 63% of the respondents are agree in development of goal. Each employee form as a goal setting strategy. This will help the employees to focus for the future and employee development.
3. 54% of the respondents are strongly agree in receiving feedback. To provide the feedback helps employees to improve their performance and remove bias.
4. 57% of the respondents are agree in performance expectations are communicated by the company. Organization give some training to improve their employee performance.

CONCLUSION

The study on the performance management system (PMS) at Manatec Electronics Pvt.Ltd. reveals that while the current framework effectively facilitates goal setting and performance reviews, it requires significant improvements in feedback mechanisms and employee engagement strategies. Enhancing these areas, along with integrating advanced performance tracking tools and continuous professional development programs, is essential for fostering a more dynamic and responsive PMS. These improvements will not only boost individual performance and employee satisfaction but also drive overall organizational success. By addressing the identified gaps and leveraging modern performance management practices, Manatec Electronics can optimize its PMS, aligning it with its strategic objectives and the evolving demands of the market.

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Chapter 60

AN ASSESMENT ON CUSTOMER SATISFACTION TOWARDS TWISSTER SOLUTIONS, COIMBATORE

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ABSTRACT

The project report titled "customer satisfaction towards twisster solutions", Coimbatore. Customer satisfaction levers the strength of organizations, which are the most essential part of growth and development of the organization. In this context, Twisster solutions is in the stage of strengthening up its marketing functions, thereby creating a need to embrace the impact of its policies on their clients. The project aims at finding the satisfaction of customer towards twisster solutions in Coimbatore which would act as a stepping stone for the company to spread the activity to the entire country. A study of company documents was initiated to understand the customer satisfaction on towards the products and services of Twisster solutions which are generic to the organization as a whole. The questionnaire was framed to find out their satisfaction and preference for the products and services of twister solutions.110 respondents were taken as sample for this study and questionnaires were distributed to obtain their response. The collected questionnaires were put under the simple percentage.

KEYWORDS

Customer satisfaction, Stepping stone, Clients.

INTRODUCTION

Customer satisfaction is a pivotal role in success of every business organization whether it is meant for a product or a service. Customers should be managed as assets, and that customers very in their needs, preferences, and buying behaviour. Customer satisfaction (often abbreviated as CSAT) is a term frequently used in marketing. It is a measure of how products and services supplied by a company meet or surpass customer expectation. Customer satisfaction is defined as "the number of customers, or percentage of total customers, whose reported experience with a firm, its products, or its services (ratings) exceeds specified satisfaction goals." Customers play an important role and are essential in keeping a product or service relevant; it is, therefore, in the best interest of the business to ensure customer satisfaction and build customer loyalty. Customer satisfaction is viewed as a key performance indicator within business and is often part of a Balanced Scorecard. In a competitive marketplace where businesses compete for

customers, customer satisfaction is seen as a major differentiator and increasingly has become an important element of business strategy. In business the term customer satisfaction refers to how well a customer's expectations have been met by the product or service provided by a particular company. Customers experience satisfaction (or dissatisfaction) in response to not only the quality of a product but also the quality of service they receive, the atmosphere of the business in which they make the purchase, and various other intangible factors. Business owners are increasingly aware that the success of their companies may depend to a significant extent upon whether they are able to attract and retain loyal customers. According to one estimate, the cost of attracting a new customer is five to seven times greater than the cost of retaining an established customer. Customer satisfaction is a key factor— some experts even argue that it is more important than price—in determining whether a customer will return to a business after his or her initial experience and whether the customer will be inclined to recommend the business to others. Customer satisfaction is an abstract concept, and it is difficult to track. It is hard to know when a customer's expectations have been met after he or she has walked out the door of your business, and it is also difficult to know when he or she has been disappointed. Research indicates that less than 5 percent of customers express their dissatisfaction directly to the company, but that the average dissatisfied customer does express his or her dissatisfaction to approximately nine other people, such as friends, family, and coworkers. In contrast, customers do not broadcast their satisfaction as widely as their complaints: it is estimated that satisfied customers tell approximately five other people about the excellent service they received or the terrific product they purchased. In general, it is widely believed that a company must figure out how to achieve a high level of customer satisfaction in order to be competitive in the marketplace.

REVIEW OF LITERATURE

S. Cecily (2022) Customer satisfaction is the overall happiness customers feel when interacting with a company's products and services as well as in comparison to what they have heard or seen about other firms or organizations. It is the basic entry point for a good business to start with. Customer loyalty, on the other hand is actually the result of an organization creating a benefit for a customer so that they will maintain their purchases from the organization. True customer loyalty is created when the customer becomes an advocate for the organization, without incentive. The objective of the study entitled 'Factors influencing customer satisfaction as well as internal processes' is to ascertain as to what extent the product related factors, customer related factors and firm related factors influence the customer satisfaction and internal processes.

Gomez and Gould (2022) observed in his study " The cool factor of public access to ICT user's perception of trust in libraries, telecaster, and cyber cafes in developing countries" that users are satisfied

with the services offered in the centers, because it links them and their communities to wider audiences, facilitates external communication and promote knowledge of computer technology among local community.

Ramzeena Azeez(2022) asserts in their study " A study on E-governance and user satisfaction through Akshaya centers in Kerala; with special reference to Marangattupilli Panchayath in Kottayam District " that most of the people in the district of kottayam are not aware about the various services provided by Akshaya centres. Akshaya is only for the citizen to provide e-governance services and provide computer education to the people especially those from rural areas. The lack of awareness of Akshaya centre creates a gap between this initiative and public. There by they are unaware of the people friendly services provided through Akshaya centers. However, the study also identifies that majority of the users are satisfied with the Akshaya centre and its services.

Gronroos (2021) "A service is a process consisting of a series of more or less intangible activities that normally, but not necessarily always, take place in interactions between the customer and service employees and/or physical resources or goods and/or systems of the service provider, which are provided as solutions to customer problems".

Looy, Gemmel &Dierdonck (2021) "Customer behavior characterized by a positive buying pattern during an extended period (measured by means of repeat purchase, frequency of purchase, wallet share or other indicators) and driven by a positive attitude towards the company and its products or services. Dissatisfaction will occur when the perceived overall service quality does not meet expectations"(Keiningham et al. 2003) "Customer satisfaction affects share-of-wallet positively"

Goran Svensson (2021)"Argued that most of the research has been done on the service receiver's perspective rather than service provider's perspective side. The author felt that
an extended penetration of service encounters, and an extended abstraction of the service quality construct, taken together, provides great potential for future research opportunities in services marketing"

OBJECTIVES

- To know the consumer satisfaction towards the after sales services offers by packaging.
- To provide suggestions, knowledgeable about the services and the company sales and profitability.
- To know the consumer perception about the safety and comfort provided by packaging.

RESEARCH METHODOLOGY

Research Design

"Descriptive research has been applied, which is also known as statistical research describes data and characteristics about the population or phenomenon being studied. Once the theoretical framework was developed, the data collection procedure was planned and executed
as research design.

Sample Design

A sample design is a definite plan for obtaining sample from a given population. Sample design method is used in selected samples.110 respondents were selected for the study.

Statistical Tools

- Percentage Analysis
- Chi-Square Test Analysis
- Correlation

FINDINGS & SUGGESTIONS

- Majority of the respondents have stated that consumer satisfaction should be effective. To develop company infrastructure and modified indoor structure.
- Increases employees and encourage the employee for their performance. Accept customer complaints and request, to improve the service.

CONCLUSION

Customer satisfaction is one of the key issues being monitored by every service provider. Thus customer satisfaction and loyalty surveys the managing level of a business can ensure a way of knowing what the customer thinks about their service and what needs to be changed to gain positive customer satisfaction. Either thus a questionnaire, a mail-in survey, an internet survey or a poll, it is very important for a business to know what their customers think about their service, how satisfied are they with what the company offers, or how loyal are the customers to their company.

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Chapter 61

A STUDY ON EMPLOYEES PERFORMANCE APPRAISAL IN KOTHARI SUGARS AND CHEMICALS LTD, KATTUR

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ABSTRACT

The aim of the study is to analyze the Performance appraisal at Kothari Sugars and Chemicals Ltd, Kattur and to give remedial measures to overcome the present situation and to implement the performance appraisal in an effective manner. So, the main objective of the study is to analyze the non-functioning of the present system and to make it effective for all levels of employees. Thus this study will help the company to know the importance of performance appraisal and also how it will be helpful in motivating the employees to perform in a better manner. Appraisal is a continuous process done annually as a formal exercise before completion of the financial year. Appraisal has tremendous motivational impact on people through meaningful feedback and is a powerful tool for recognition. This project explains performance appraisal system and tries to find out how efficiently performance appraisal is conducted. And if performance appraisal doesn't meet its objective then, what are the factors causing failure

OBJECTIVES

Primary objectives

A study on Employees performance appraisal in Kothari Sugars and Chemicals Limited, Kattur.

Secondary objectives

- To find the satisfaction of the employees with the existing performance appraisal system.
- To analyze the promotion is purely based on performance appraisal.
- To analyze the performance appraisal helps in individual goals and organizational goals.

LITERATURE REVIEW

Review of literature is said to be a previous study conducted by a person on the topic. In that he/she analyses about a problem and he/she may suggest some solution to solve the problem. From collecting studies, the researchers may get some ideas about the concept and it helps the researchers in preparing the questionnaire and it also enhance the researchers to know more about the topic and latest information's related the study.

Okoth and Florah (2021) The aimed to establish the influence of performance appraisal on motivation of public secondary school teachers in Gem Sub- County. The findings of the study revealed that fairness and impartiality in performance appraisal system, performance appraisal feedback, performance rewards and performance goal setting had a positive and significant effect on teacher motivation in Gem sub-country

Ramila Ram Sign &S.Vadivelu (2020) The mentioned in their paper about the performance appraisal in India. Retention of' the employees in the organization is a difficult task for the management. Motivation plays a key role in this aspect. Performance appraisal is a tool to know the employee performance in various aspects, It is useful for salary increment, promotion, staff retention and to reinforce staff behaviour. above referred literature shows that Performance Appraisal is only tool in assessing the employee's tasks and responsibilities matching their capability. A comparison has been done in public and private sector enterprises where private sector appraisals have been more effective.

DATA COLLECTION METHOD

Collection of data is the first step in statistics. The data collection process follows the formulation for research design including the sample plan. The data can be secondary or primary.

Primary Data

Primary data is the new or fresh data collected from the respondents through structured scheduled questionnaire.

Secondary Data

The secondary data means data that is already available i.e., they refer to data, which has already been collected and analysed by someone else.

The secondary data were collected from:

- Magazine
- Books
- Journals
- Record maintained by HR department
- Company Websites.

STATISTICAL TOOL USED

- Percentage analysis
- Chi – square test
- Correlation test

FINDINGS

- Majority 49% of the respondents are satisfied with the existing performance appraisal system.
- Majority 44% of the respondents are having 3- 6 years of work experience
- Majority 38% of the respondents are agreeing with the promotion is purely based on performance appraisal.
- Majority 48% of the respondents are agreeing with the appraisal helps in individual goals and organizational goals.

SUGGESTION

According to this survey you already giving the great appraisal system that will reduce the employee's grievances. So, keep continued this appraisal system that will helpful for the future improvement of the organization. The respondents are having negative opinion towards the performance appraisal increases employee's motivation. So, the organization has to improve the Performance appraisal system should motivate the employees and increase their performance level in their work.

CONCLUSION

The research entitled "A Study On Employees Performance Appraisal in Kothari Sugars and Chemicals Ltd, Kattur" was undertaken to know about the performance appraisal system in the organization. The result observed and achieved in this project clearly indicates that there exists a proper performance appraisal system in the organization. Performance appraisal is an important part of an organization but the performance appraisal process is incomplete without the feedback given to the employee about his appraisal and his performance. The way performance appraisal is conducted will lead to employee's satisfaction and will ultimately help the organization in achieving its goals. The employee training and development programs, target-based appraisal, performance related pay for employees, feedback of the employees all these to improve their performance. The appraisal system is made on the aim to improve the employee performance the positive effect on employee's performance. Business environment condition affect on organization overall performance and employee performance as well. In addition, it is concluded that the performance appraisal play key role in any organization success.

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