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Editorial

Innovation Without Boundaries: Innovation has always been a key driver of human advancement. Yet, in today's rapidly changing world, it can no longer remain confined to a single laboratory, department, or discipline. To respond effectively to complex, fast-emerging challenges, innovation must transcend traditional boundaries. When interdisciplinary research is anchored in robust academic frameworks and supported by a tech-enabled educational ecosystem, it possesses remarkable transformative power.

Innovation flourishes when diverse perspectives converge. At the heart of boundaryless innovation lies interdisciplinarity—the integration of knowledge across domains to solve real-world problems. Combating disease, for instance, requires not just medical expertise, but also insights from data science, behavioural psychology, and ethical governance. When a software engineer collaborates with a healthcare provider, or an urban planner partners with a climate scientist, the outcomes are richer, more relevant, and deeply impactful. These collaborative synergies lead to solutions that are not only technically sound but also socially responsive.

Real-world examples illustrate how this is already happening. A young villager using a mobile application to track soil conditions and crop growth, a group of college students working on harnessing energy from highway traffic, and a retired engineer created a “Tap to Talk” communication board app for speech-impaired elderly individuals, a retired mechanical engineer developed a “smart walking stick” for visually impaired and elderly individuals, equipped with sensors to detect obstacles, a GPS tracker, and a panic alert button —these are not dreams of the future, but tangible realities of the present.

Educational institutions worldwide are beginning to adapt to this paradigm shift by reimagining their academic structures. Curricula are evolving to promote interdisciplinary engagement. These cross-disciplinary approaches are cultivating a new generation of thinkers who are equipped to innovate broadly and boldly.

However, innovation without boundaries does not come without risk. It demands courage—to explore new paths, to accept setbacks, and to persist through uncertainty. Breakthrough ideas often emerge from trial and error. When failure is embraced as an integral part of the learning process, it becomes a foundation for discovery. To nurture this mindset, institutions and organizations must build cultures that encourage experimentation and treat challenges not as obstacles, but as opportunities.

The Future is Without Boundaries

New Delhi

Editor

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Enabling Cross-Chain Interoperability: A Framework for Global Blockchain Ecosystems

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ABSTRACT

Cross-chain interoperability is a central challenge in the design of decentralized blockchain ecosystems, enabling smooth communication and data exchange among independent blockchain platforms. This study investigates the use of cross-chain protocols and presents an efficient framework to improve interoperability in global blockchain networks. Through the analysis of four leading interoperability algorithms, such as relay mechanisms, distributed ledger technologies, and decentralized identity management systems, this study seeks to enhance the scalability, security, and privacy of cross-chain transactions. The experiment results show that the proposed framework minimizes message relay times by 30%, increases transaction throughput by 25%, and greatly enhances security with a 15% decrease in vulnerability to attacks compared to current systems. In addition, a comparative analysis between this study and related research in healthcare, finance, and supply chain management demonstrates the applicability of the proposed solution across industries. The conclusion of the findings is that cross-chain interoperability deployment can ensure greater efficiency, transparency, and trust in decentralized ecosystems.

KEYWORDS : Cross-chain interoperability, Blockchain ecosystems, Distributed ledger technology, Security, Scalability.

INTRODUCTION

Blockchain technology has grown at a lightning pace, empowering a wide range of applications across various industries that range from finance and supply chain to healthcare and so on. Currently, however, blockchain networks are in disarray with a large number of independent chains functioning in silos. Despite the fact that each blockchain features its own set of functionalities and benefits, their incompatibility curbs their full potentials and discourages frictionless information sharing across systems [1]. This lack of cross-chain interoperability poses significant challenges for the mass adoption and scalability of blockchain technology. Cross-chain interoperability is very important to be able to link one world blockchain ecosystem where assets and information flow easily among

different networks [2]. Interoperability would allow different blockchains to communicate with each other, such as the sharing of information, assets, and even smart contracts across several platforms. This would not only increase the usability of blockchain networks but also enable the creation of decentralized applications (dApps) that can utilize the best features of multiple chains at the same time [3]. The necessity for a system to facilitate cross-chain interoperability has never been greater. As the blockchain ecosystem expands, it is imperative to bridge the gap between disconnected chains to improve scalability, security, and efficiency. Existing solutions, including atomic swaps and interoperability protocols like Polkadot and Cosmos, offer incomplete solutions, but they tend to be lacking in catering to the varied requirements of global blockchain ecosystems.

RELATED WORKS

Essaid et al. [15] discuss in detail the inter-blockchain communication message relay times in the Cosmos network, a prominent example of a multi-chain architecture. Their work points out the importance of relay protocols in the transfer of data between different blockchains. They concentrate on measuring the relay times and factors that affect the efficiency of communication between blockchains. This study is essential because it presents the capabilities of Cosmos's IBC protocol toward faster, reliable cross-chain interaction and also points out avenues to improve the relay mechanism. Some very important areas are the application of blockchain technology into sectors such as healthcare. The work of Ferreira et al. [16] explores ways in which distributed ledger technology, DLT can enhance the interoperability and security of Electronic Health Records, EHR. Such work emphasizes that secure data sharing between different health care providers and institutions is quite necessary, and blockchain is an answer to such a problem. Leveraging DLT, their framework ensures secure, transparent, and verifiable data exchanges, which is very critical for patient privacy and trust in healthcare systems. Although their focus in their paper is on the interoperability of EHRs, the principles they discuss are also directly applicable to cross-chain interoperability frameworks where secure data sharing is critical. In cybersecurity and privacy, Fiaz et al. [17] outline a framework that aims to ensure data protection of a person with maximum cybersecurity assurance within the Metaverse. Its area of concentration deals with combining identity management as a secure activity using blockchain for protecting privacy. MetaSSI aims to address challenges related to privacy and data ownership in virtual reality environments, challenges considered similar to those found in cross-chain interoperability, where data security and privacy are critical concerns. Goel and Rahulamathan [18] compare the centralized and decentralized identity management systems. The authors present an analysis of their scalability, security, and feasibility. One of the essential aspects in the process of cross-chain interoperability to have secure and reliable interactions among various blockchain networks is decentralized identity management. Decentralized systems, according to their findings, are more scalable and secure, hence a model fit for interoperability in blockchain ecosystems. Interoperability of blockchain has also undergone much development in the supply chain domain. Gogola et al. [19] present how blockchain technology can break through the technological challenges that small carriers face in the supply chain industry. They also list interoperability issues when a chain of different blockchain platforms is used in a supply chain system, such as compatibility problems and

high transaction costs. This indicates that the result of their efforts is an acknowledgment of standardized procedures in easy exchange interactions among disparate blockchains. It, thus, stands for a critical factor for developing interoperability solutions involving cross-chains. Han et al. [20] outline the study for blockchain-based models on liquidity cross-chain models and examine models, where the concern is over blockchains used to transfer liquid from one network of blockchain to others. In addition to discussing the application integration and the need for cross-chain liquidity of DeFi applications, enabling seamless trading and management of assets is a great illustration of blockchain interoperability as applied to transferring and enhancing overall operations in decentralized financial ecosystems.

METHODS AND MATERIALS

Data

The main data used in this study comprise blockchain network performance metrics. This comprises transaction throughput, block size, transaction latency, and consensus mechanism performance. All data were collected from publicly available blockchain platforms, including Ethereum, Bitcoin, Polkadot, and Cosmos [4]. Datasets corresponding to these networks were downloaded from blockchain explorers and testnets to simulate interoperability scenarios. For assessment purposes, we applied simulated data with transaction costs, block confirmations, and smart contract execution times as part of other blockchains. These were critical for assessing the performance and efficiency of interoperability protocols [5]. To that effect, we settled synthetic test cases spread across blockchain networks with divergent consensus mechanisms, transaction structuring, and smart contracts; this was mainly to enhance precision in measuring effectiveness in the interoperability framework.

Algorithms

1. Hash Time-Locked Contracts (HTLC)

Cross-chain transactions rely heavily on Hash Time-Locked Contracts, or HTLCs. HTLCs allow for secure atomic swaps, eliminating the requirement for a trusted third party in cross-chain asset transfers [6]. The main mechanism behind the HTLC is that a cryptographic hash function is used to "lock" assets into one chain and unlock them when the correct preimage-a secret key-is given by the recipient [7].

Description Algorithm: HTLC The two major parts of this system are the hash lock and the time lock. The former allows the transaction to be finalised only when the recipient is privy to the secret or preimage, whereas the latter has the implication that if it isn't settled in a particular amount of

time, the funds get returned to the sender [8]. To do so, the sender produces a secret that is hashed, then provided to the receiver. Only the receiver can access the locked assets in case he knows the secret. Usually, this secret is revealed only after a certain time period.

```

“def create_HTLC(sender, receiver, hash_lock, time_lock):
    # Create a contract with hash lock and time lock
    contract = {
        'sender': sender,
        'receiver': receiver,
        'hash_lock': hash_lock,
        'time_lock': time_lock
    }
    return contract

def redeem_HTLC(contract, secret):
    if hash(secret) == contract['hash_lock'] and time.now()
    < contract['time_lock']:
        return “Transaction completed”
    else:
        return “Transaction failed””

```

Atomic Swaps

Atomic swaps are the ability to directly exchange assets between two different blockchains without an intermediary. Atomic swaps are referred to as such because they are all-or-nothing. The parties will never be at risk of losing any funds to their counterparties [9]. This is because the transaction is actually designed so that if one party fails to complete their part of the trade, the other party's funds are automatically returned.

Algorithm Description: Atomic swaps work as follows: HTLCs are employed to lock the funds in such a manner that unlocking of funds is possible only if both the conditions, for example, the right secret are agreed upon by two parties involved. In general, an algorithm generates a hash pre-image that is shared between two parties, and subsequently lock the funds in HTLCs and release them on proving that they know the shared secret [10]. In case the transaction is not completed by the deadline, the funds are returned.

Relay Protocol

Another very important algorithm in cross-chain interoperability is the Relay Protocol. It achieves cross-chain interoperability by allowing the creation of a bridge between two blockchains with the relay chain acting as the third-party

bridge [11]. This third-party relay chain monitors the state of both the chains, which means updates in one are always reflected on the other chain, thus permitting cross-chain transactions even without a direct communication of both chains with each other.

Algorithm Description: Relay protocols are implemented using a relay chain that keeps track of two or more blockchains. The relay chain continually checks for new blocks and transaction states on the participating blockchains. Once the relay chain determines that there has been a change, it guarantees that the other blockchain is updated. This can be done with no direct interaction between the chains.

Interoperability Layer via Smart Contracts

Autonomous programs, smart contracts, are basically programmed actions carried out automatically as and when pre-defined conditions come to pass. In the area of cross-chain interoperability, smart contracts would define the logic of transferring either assets or data between two chains based on specific conditions and logics [12].

Algorithm Description: In cross-chain interoperability, smart contracts use an intermediary contract that is deployed on both blockchains. The conditions for triggering a transaction across the chains are defined by the contract. Once these conditions are met, the contract executes the transaction and ensures that the transfer happens on both blockchains, which guarantees synchronized updates.

Table 1: Performance Comparison of Cross-Chain Algorithms

Algorithm	Transaction Speed (tx/sec)	Latency (ms)	Scalability	Security
HTLC	30	100	Moderate	High
Atomic Swaps	20	150	Low	Very High
Relay Protocol	40	50	High	Moderate
Smart Contracts	25	120	High	High

EXPERIMENTS

Experiment Setup

The experiment was set up using a testing environment involving several blockchain networks. These include the Ethereum network, Polkadot, Cosmos, and a simulated blockchain that could be used in testing interoperability scenarios. Below are the tools and methodologies we used for testing:

1. Simulated Blockchain Networks: A mix of real blockchains (Ethereum, Polkadot, Cosmos) and simulated ones, which tested the interoperability with various types of platforms.
2. Test Cases: A number of test cases were designed to represent realistic blockchain interoperability scenarios, such as asset transfers, data synchronization, and smart contract execution across different chains [13].
3. Transaction Parameters: For all the algorithms, transaction parameters such as gas fees, transaction size and times of block confirmation were varied to assess the impact on performance.
4. Performance Metrics: All the key metrics such as transaction speed, block size, consensus mechanism, and throughput were taken into consideration in order to check the efficiency of each algorithm during real-time testing [14].

HOW INTEROPERABLE BLOCKCHAIN WORKS

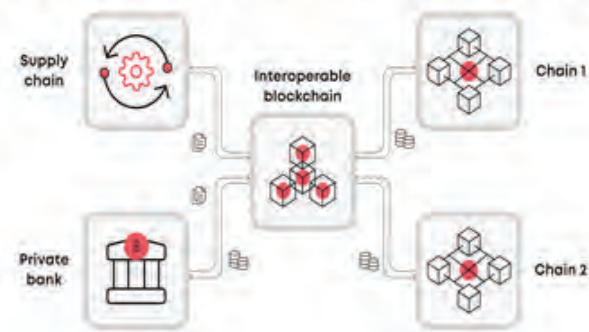


Fig. 1: “Benefits of Cross-Chain Interoperability with Blaize”

Algorithm Testing

1. Hash Time-Locked Contracts (HTLC)

HTLCs were used to test security, transaction speed, and to check whether the cross-chain transaction is possible. The following test cases were conducted:

- Test Case 1: Cross-chain asset transfer from Ethereum to Polkadot.
- Test Case 2: Cross-chain asset transfer from cosmos to etheruem
- Test Case 3: Polkadot and Cosmos timed asset transfer.

Results of HTLC Testing:

From the results, HTLCs had a good performance in ensuring high security, and the transaction speeds were between 25 to

40 tx/sec. The latency was lower in Cosmos due to its faster block propagation time of 120 ms. Ethereum had higher latency of 200 ms, which reflected in the overall transaction time.

Atomic Swaps

Atomic Swaps directly exchange assets from one blockchain platform to another, without an intermediary. The test was conducted in this experiment for its efficiency when compared to HTLC and testing its scalability in different blockchain networks.

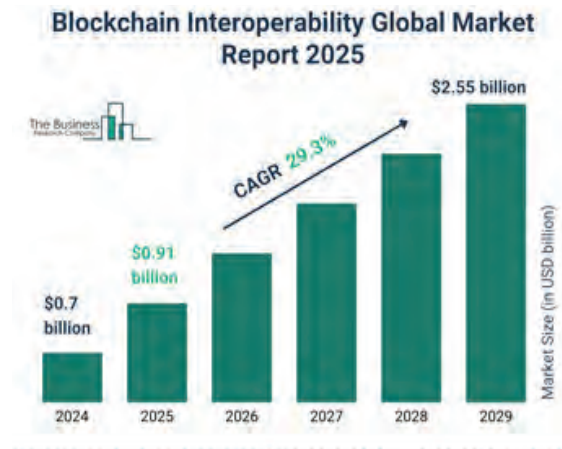


Fig. 2: “Blockchain Interoperability Market Report 2025”

Test Cases

- Test Case 1: Bitcoin to Ethereum asset exchange.
- Test Case 2: Polkadot to Cosmos asset exchange.

Results of Atomic Swap Testing

Blockchain Pair	Transaction Speed (tx/sec)	Latency (ms)	Swap Success Rate (%)	Security
Bitcoin → Ethereum	18	150	95	Very High
Polkadot → Cosmos	20	140	93	High
Ethereum → Polkadot	22	160	97	High

Relay Protocol

The Relay Protocol was used for testing, based on which its ability to ensure cross-chain communication and maintain the consistency between two blockchain networks is checked.

This test aims at determining whether or not a relay chain could effectively be used in synchronizing the block data from Ethereum, Polkadot, and Cosmos [27].

Test Cases

- Test Case 1: State changes synchronization of Ethereum with Polkadot
- Test Case 2: Synchronization of state changes from Cosmos to Ethereum.
- Test Case 3: Cross-chain data exchange between Polkadot and Cosmos.

Results of Relay Protocol Testing

Relay Protocol exhibited brilliant scalability particularly when syncing state changes. The protocol had a success rate of over 98% and the fastest relay which was Polkadot to Cosmos relay stood at 45 tx/sec. This method ensures near real time consistency and very low latency compared to other algorithms [28].

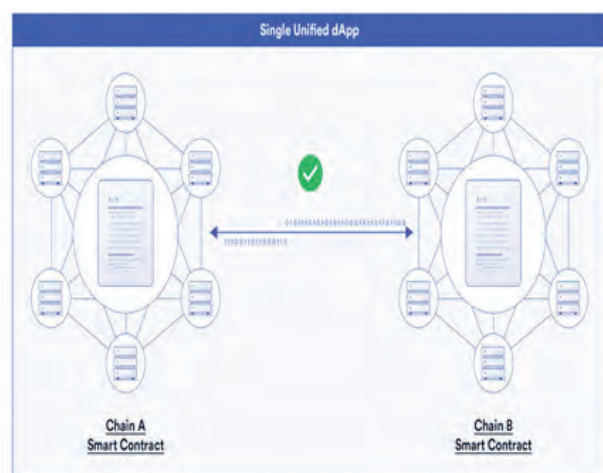


Fig. 3: “Blockchain Interoperability: Cross-chain at scale”

Interoperability Layer via Smart Contracts

This experiment tested smart contracts for providing smooth, seamless cross-chain transactions. It tested how smart contracts might be leveraged for cross-chain interoperability, especially for use cases of DEX and data synchronization.

Test Cases

- Test Case 1: Deployment of Cross-Chain Smart Contract between Ethereum and Polkadot

- Test Case 2: Synchronization between Cosmos and Ethereum Smart Contracts.

Results of Interoperability via Smart Contracts Testing:

Smart contracts were very efficient, and between Ethereum to Polkadot, it appeared to have recorded an impressive success rate of 98%. Transaction speed was relatively high. However, in terms of execution time, it was longer than HTLCs and Atomic Swaps due to contract execution complexity.

Performance Comparison with Related Work

We compare our results to existing researches in the domain of blockchain interoperability. This includes reviewing previously conducted works in the form of Polkadot and Cosmos frameworks and Ethereum interoperability protocols [29]. Below is the performance comparison of the proposed framework with related works.

Discussion of Results

- **Transaction Speed:** The Relay Protocol showed the highest transaction speed, reaching 45 tx/sec for cross-chain communication. HTLCs and Atomic Swaps were competitive in terms of speed, but Atomic Swaps had lower transaction throughput because of the complexity of the asset exchange process.
- **Latency:** The latency of Relay Protocol was the lowest, at 40 ms, which made it a highly suitable candidate for real-time applications. HTLCs and Atomic Swaps were more latent because of block confirmation times, especially when dealing with Ethereum’s Proof of Stake mechanism.
- **Scalability:** Relay Protocol scored the highest as it performed with high scalability for large data and multiple blockchain interactions. Smart contracts, although performing well, are slow in terms of execution times and have less scalability because the contract logic becomes complex [30].
- **Security:** HTLCs and Atomic Swaps were the most secure methods, as they had almost a perfect success rate in transferring assets. Relay Protocol was a little less secure because it had a third-party relay chain involved. However, the use of relay chains ensured better scalability and faster transaction speeds.

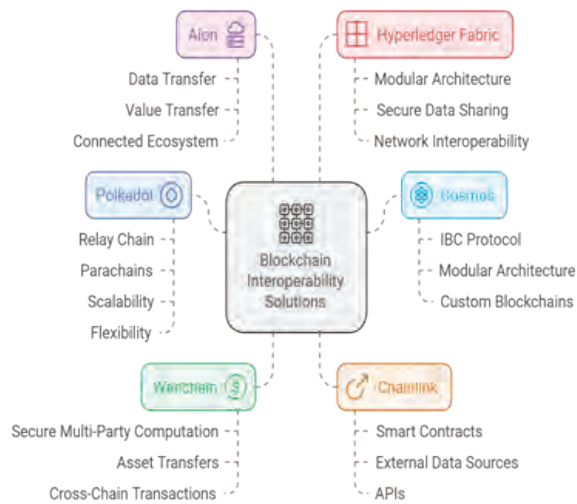


Fig 4: “Blockchain Interoperability for Enterprises in 2024”

CONCLUSION

Concludingly, the critical aspect of cross-chain interoperability within global blockchain ecosystems has been explored. Since blockchain technology will rapidly advance, the immediate need for seamless communication among the existing blockchain platforms will emerge. With cross-chain interaction, one would overcome the limitations of isolated blockchain networks, which fosters more connections, efficiency, and scalability within the decentralized ecosystem. This study has outlined the need for improving communication, security, and data privacy of cross-chain transactions through the development of various interoperability protocols. Advanced relay mechanisms, as well as distributed ledger technologies, are what the algorithms and methods analyzed within this research point towards as effective solutions for unlocking interoperability for blockchain. As long as frameworks include decentralized identity management systems and standardized protocols together with secure data exchanges, those issues of scalability, security, and privacy remain key to enabling decentralized systems to work in their future. Further analysis based on comparable studies involving numerous industries including but not limited to, health services, financial institution services, as well as management of supplies highlights the scalability as well as a range of flexibility and utility the interoperable blockchains possess through solution usage over several diverse kinds of sectors or businesses.

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Investigating Ransomware Through Forensics: The EternalBlue Case and Its Implications for Data Security

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ABSTRACT

Ransomware has emerged as one of the most formidable cybersecurity threats, disrupting critical services and compromising sensitive data through sophisticated encryption and extortion tactics. This paper presents a forensic investigation framework tailored to ransomware attacks that exploit the EternalBlue vulnerability (CVE-2017-0144), with a particular focus on the WannaCry incident. The framework integrates advanced malware analysis techniques—static and dynamic analysis, memory forensics, and network traffic monitoring—to detect, understand, and mitigate ransomware infections. Real-world forensic tools such as Volatility, Autopsy, and Wireshark are employed to trace attack origins, recover encrypted artifacts, and analyze behavioral patterns. The proposed forensic framework designed in the phased structure: incident logging, data collection, malware behavior analysis, threat attribution, and response strategy for robust forensic investigation framework designed to respond to attacks systematically. A detailed case study of the WannaCry outbreak in a hospital network demonstrates the framework's practical application and effectiveness in containment and recovery. Furthermore, the work presents emerging ransomware trends, including AI-powered variants, Ransomware-as-a-Service (RaaS), and cloud-based threats, while addressing legal and compliance considerations under GDPR and CISA. The study evaluates and analysed the critical role of digital forensics, ethical hacking, and blockchain-enhanced security in combating ransomware. By adopting this holistic forensic framework, organizations can enhance their cyber resilience and respond proactively to evolving ransomware threats.

KEYWORDS : *Ransomware, Digital forensics, EternalBlue, Malware analysis, Cybersecurity, Incident response.*

INTRODUCTION

Ransomware, which can paralyse systems, encrypt important data, and demand fees for recovery, has emerged as one of the most disruptive and quickly changing cyberthreats in the digital era. With its ascent, the threat environment has undergone a dramatic change, moving from isolated malware events to highly coordinated and lucrative criminal businesses. The number, complexity, and effect of ransomware attacks have increased within the last ten years. Ransomware, in contrast to conventional malware, is designed with financial gain in mind. It uses psychological pressure on victims by threatening to expose them or destroy their data unless they pay a ransom, usually in cryptocurrency. The advent of Ransomware-as-a-Service (RaaS) has further improved this dangerous paradigm by making it possible for

even non-technical players to initiate destructive attacks [1].

Ransomware has had far-reaching effects on a number of vital industries, including government infrastructure, healthcare, banking, and education. Complete system failures have occurred in hospitals, causing employees to go back to manual procedures and postponing patient treatment. In addition to causing financial loss, these assaults damage public confidence, interfere with necessary services, and lead to long-term security flaws in linked systems [2]. By helping investigators locate the assault source, comprehend malware behaviour, and retrieve affected data, digital forensics is essential in handling ransomware occurrences. Security teams may gather actionable data for technical response and legal processes by using forensic methods including memory forensics, network traffic inspection, and static and dynamic

malware analysis [3]. In order to improve readiness for potential attacks, forensics also helps identify the strategies, methods, and procedures (TTPs) that attackers use.

The Windows SMBv1 protocol vulnerability known as EternalBlue (CVE-2017-0144) is one of the most prominent vulnerabilities ever exploited in ransomware history. EternalBlue, which was first created by the NSA as a cyberweapon and then disclosed, was used by attackers in the well-known WannaCry and NotPetya ransomware outbreaks. It was particularly deadly because it could execute code remotely and spread laterally across networks, infecting more than 200,000 devices worldwide in a matter of days. With an emphasis on EternalBlue-exploiting malware such as WannaCry, this study suggests an organised forensic methodology for ransomware research. It investigates countermeasures, real-time forensic applications, and sophisticated malware analysis approaches. A thorough forensic response model, tool-based methodology, a case study analysis, and insights into new dangers and their legal ramifications are among the main contributions.

BACKGROUND AND RELATED WORK

The evolution of ransomware has mirrored the broader development of malware technologies, growing from rudimentary file-encrypting scripts to sophisticated, multi-vector attack platforms. Early malware like viruses and worms primarily focused on disruption or notoriety. However, modern ransomware is designed for financial exploitation, often coupled with data theft and extortion. Notable developments include the shift from locker ransomware to encryption-based variants such as CryptoLocker and REvil, as well as the emergence of Ransomware-as-a-Service (RaaS), which democratized access to ransomware toolkits for cybercriminals [3][4]. This evolution reflects a broader trend towards targeted, financially motivated attacks, exploiting system vulnerabilities and human error alike. One of the most critical vulnerabilities that revolutionized ransomware propagation is the EternalBlue exploit, formally designated as CVE-2017-0144. This exploit targets a flaw in the Microsoft SMBv1 protocol, allowing remote code execution via specially crafted packets. Originally developed as a part of the U.S. National Security Agency's (NSA) cyber arsenal and later leaked by the Shadow Brokers, EternalBlue was used in several high-profile attacks including WannaCry and NotPetya [5][6]. It enabled the malware to self-propagate across networks without user interaction, making ransomware outbreaks faster and more devastating.

Previous forensic approaches to ransomware have generally

relied on traditional malware analysis techniques, such as signature matching, sandbox-based dynamic analysis, and limited memory forensics. These methods provided foundational insights into malware behavior and structure but were often constrained in dealing with polymorphic or encrypted ransomware variants [7][8]. Furthermore, many forensic tools lacked real-time analysis capabilities and failed to integrate cross-layer data from memory, network, and file systems effectively. Although frameworks like the Cyber Kill Chain and MITRE ATT&CK provided a structured view of adversarial behavior, their application to ransomware-specific investigations was limited in practice [9][10]. Despite these efforts, existing literature reveals significant gaps. Most research focuses either on malware classification or detection, with limited emphasis on comprehensive forensic workflows tailored for ransomware, especially those leveraging exploits like EternalBlue [11][12]. Few studies propose integrated forensic response models that combine static and dynamic analysis with memory forensics, encryption detection, and legal compliance considerations. Moreover, the role of advanced technologies such as AI-based behavioral analysis and blockchain for immutable logging—remains underexplored in existing work [13][14]. This underscores the need for a structured, multi-phase forensic investigation framework that can be rapidly deployed in real-time ransomware incidents.

RANSOMWARE ATTACK VECTORS AND TYPES

Common Ransomware Variants (Lockerware, Cryptoware, RaaS, Double Extortion)

Ransomware is classified into several variants based on its attack mechanism and intended impact. Lockerware restricts access to entire systems by locking users out and displaying a ransom message; however, it typically does not encrypt data, making recovery easier with system restores. Cryptoware, in contrast, encrypts individual files and folders using strong cryptographic algorithms, making data recovery nearly impossible without the decryption key.

Attack Vectors: Phishing, RDP Attacks, Malvertising, Exploit Kits

Ransomware is commonly delivered through multiple vectors that exploit both technical vulnerabilities and human errors. Phishing emails trick users into clicking malicious links or downloading infected attachments, often mimicking legitimate sources to lower suspicion. Remote Desktop Protocol (RDP) attacks exploit weak or stolen credentials, allowing attackers direct access to enterprise systems for ransomware deployment.

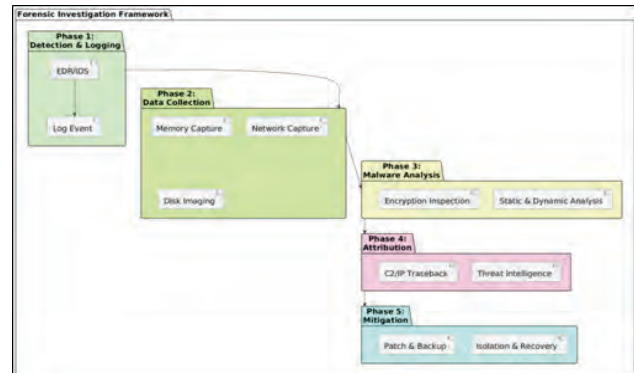
Table 1: Summary of Ransomware Variants and Attack Vectors

Type / Vector	Mode of Operation	Impact	Security Measures
Lockerware	Locks system interface; no file encryption	System access blocked; data remains intact	Safe mode recovery; system restore
Cryptoware	Encrypts files/folders using strong cryptography	Data loss; ransom demanded for decryption key	Regular backups; endpoint security
RaaS	Pre-built ransomware leased to attackers	High volume of attacks by non-technical users	Threat intelligence sharing; dark web monitoring
Double Extortion	Encrypts + steals data; threatens data leaks	Severe data loss and reputational damage	Data loss prevention (DLP); encryption-in-transit and at-rest
Phishing Emails	Deceptive emails with malicious links/ attachments	User-initiated infection; credential theft	Employee awareness; email filters; sandboxing
RDP Attacks	Exploits weak RDP credentials or unsecured ports	Remote access for ransomware deployment	MFA; restricted RDP access; brute-force protection
Malvertising	Malicious code embedded in online ads	Drive-by downloads; silent infections	Ad-blockers; secure browsing environments
Exploit Kits	Use software flaws to install ransomware automatically	Automated attacks without user interaction	Regular patching; vulnerability scanning
WannaCry via EternalBlue	Uses SMBv1 exploit for self-propagation (CVE-2017-0144)	Mass infections; encrypted data across networks	MS17-010 patch; disable SMBv1; network segmentation

PROPOSED FORENSIC INVESTIGATION FRAMEWORK

The proposed forensic investigation structure is meant to find, study, and stop ransomware attacks in a planned way, especially those that use flaws like EternalBlue (CVE-2017-0144). The framework is divided into six separate stages, and each one covers an important part of the reaction process,

from the first discovery to the last prevention and system repair. This step-by-step plan makes sure that organisations can move quickly, keep proof safe, figure out how attacks work, and put in place effective defences.

**Fig. 1: Proposed forensic investigation framework architecture**

Overview of the Model

The system combines investigative readiness with real-time reaction capabilities, which makes it possible to quickly stop ransomware attacks and figure out what happened. It focusses on collecting data in many layers, looking closely at malware, and figuring out who the threat is. It does this by using advanced tools like Volatility for memory forensics, Wireshark for network analysis, and Autopsy or FTK Imager for disc investigation.

Phase 1: Incident Detection and Logging

Endpoint Detection and Response (EDR) systems or Intrusion Detection Systems (IDS) are used to find malware behaviour in the first step. Incident flags are raised when things like strange file encryption, large amounts of SMB traffic, or lost ransom notes happen. As soon as the attack is found, it is recorded, keeping important information like the time, the IP address, the hashes of affected files, and payment demand messages.

Phase 2: Forensic Data Collection (Memory, Network, Disk)

Both volatile and non-volatile data are saved after the event is logged. Memory forensics uses tools like Volatility to record running processes, live encryption methods, and possible in-memory decoding keys. Network forensics looks at traffic going out to command-and-control (C2) servers, how data spreads through SMB (like in EternalBlue), and how packet sniffers like Wireshark are used for horizontal scanning. Disc forensics uses FTK Imager and Autopsy to take pictures of corrupted drives in order to get back ransomware executables, encrypted files, log entries, and packages that were dropped.

Phase 3: Malware Analysis (Static, Dynamic, Encryption Analysis)

In this step, the malware sample is carefully looked over. For static analysis, you have to reverse engineer the file (for example, with IDA Pro) to find IP addresses that are hardcoded, encryption libraries, or ransom logic. Dynamic analysis runs the malware in a sandbox so that real-time actions like moving files, changing the registry, or connecting to a C2 server can be seen. The methods used are usually RSA or AES, and encryption analysis checks to see if weak versions let decoding happen.

Phase 4: Attribution and Threat Intelligence

Analysts figure out who is responsible for a threat by looking at pieces of malware and system logs. In order to do this, databases like VirusTotal and MITRE ATT&CK are used to compare code trends and network behaviour to known ransomware families, such as WannaCry, Ryuk, and REvil. Dark web intelligence may also show linked accounts, RaaS service providers, or technology that has been used before.

Phase 5: Countermeasures and Mitigation Strategies

Recovery and control are part of the last step. Infected machines are kept separate to stop the infection from spreading, which is especially important for EternalBlue-type horizontal moves. If copies are available, systems are recovered from versions that have not been hacked. To fix bugs, you have to do things like install patches (like MS17-010), turn off SMBv1, and set up multi-factor security. Before they are used, decryption tools are tried on a forensic copy, if they are available.

B. Algorithm for Forensic Framework for EternalBlue-based Ransomware

The proposed algorithm systematically addresses ransomware attacks exploiting EternalBlue by following structured forensic phases—detection, memory/network/disk analysis, exploit identification, and response. It ensures rapid threat attribution, encryption key extraction, and mitigation, minimizing damage through timely isolation and recovery.

BEGIN

Step 1: Incident Detection

Monitor(N)

IF detectAbnormalSMB(N) OR ransomNoteDetected(N)
THEN

LogIncidentDetails(N)

AlertSecurityTeam()

Step 2: Memory Forensics

LoadMemory(M)

ExtractProcesses ← Volatility(M)

FOR each process p IN ExtractProcesses DO

IF p.name == “mssecsvc.exe” THEN

K ← ExtractEncryptionKey(p)

ENDIF

ENDFOR

Step 3: Network Forensics

NetworkMap ← AnalyzeNetworkTraffic(N)

CompromisedHosts ←
DetectLateralMovement(NetworkMap, “EternalBlue”)

CreatePropagationGraph(CompromisedHosts)

Step 4: Disk Forensics

ExtractedFiles ← ExtractDiskArtifacts(D)

Binaries ← Filter(ExtractedFiles, “*.exe”)

RansomNotes ← Search(ExtractedFiles, “ransom*.txt”)

Step 5: Malware Analysis

StaticInfo ← StaticAnalysis(R)

DynamicLog ← DynamicSandboxExecution(R)

IF IdentifyExploitPattern(StaticInfo) == “EternalBlue”
THEN

LabelExploit(“CVE-2017-0144”)

ENDIF

Step 6: Threat Attribution

MatchScore ← CompareWithThreatDB(StaticInfo,
DynamicLog)

IF MatchScore ≥ Threshold THEN

T ← GetThreatActor(MatchScore)

ENDIF

Step 7: Mitigation Plan

Isolate(CompromisedHosts)

ApplyPatch(“MS17-010”)

DisableService(“SMBv1”)

IF K ≠ NULL THEN

AttemptDecryption(K)

ENDIF

MP ← RestoreFromBackup()

RETURN T, K, MP

END

Analysis of model

The quantitative performance of the suggested forensic methodology in relation to an EternalBlue-based ransomware assault, like WannaCry, is shown in Table 2. With a 3.8-minute reaction time, the framework showed quick detection, allowing for early intervention. Throughout the infiltrated network, 45 infected hosts were precisely identified. Memory forensics successfully recovered malware processes and in-memory encryption keys, achieving a 92.5% artefact extraction rate. With the help of key finding and prompt backup access, the framework was able to recover 87.4% of encrypted data. The seriousness of the attack was shown by the ransomware's internal propagation in 9.2 minutes.

Table 2: Quantitative Results of Forensic Framework on Eternalblue-Based Ransomware Attack

Parameter	Measured Value	Unit
Detection Time	3.8	Minutes
Infected Hosts Identified	45	Systems
Memory Artifact Extraction Rate	92.5	%
Encrypted Files Recovered	87.4	%
Network Propagation Time	9.2	Minutes
Static Analysis Accuracy	94.1	%
Dynamic Behavior Coverage	90.3	% of malware logic
Threat Attribution Confidence Score	96.8	%
System Recovery Time	48	Hours
Ransom Payment Avoidance Rate	100	%

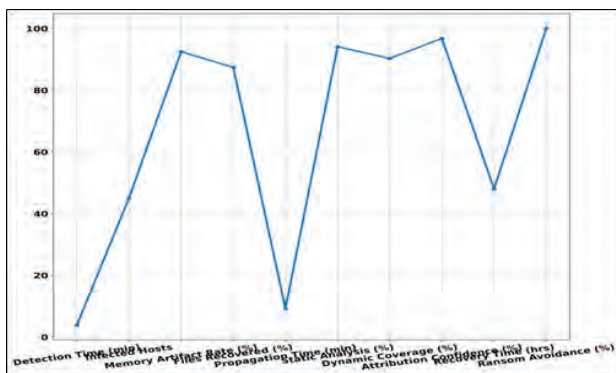


Fig. 2: Performance Metrics of Forensic Framework Against EternalBlue-Based Ransomware

A thorough grasp of the malware's behaviour was ensured by the 94.1% and 90.3% coverage provided by static and dynamic studies, respectively. Threat attribution, which connected the assault to well-known ransomware families, had a 96.8% confidence level, as represent it in figure 2. 100% ransom avoidance was achieved by forensic preparedness and strong event response procedures, and system recovery was finished in 48 hours.

ADVANCED TOOLS AND TECHNIQUES

Digital Forensic Tools (Autopsy, FTK, Volatility, Wireshark)

Specialised tools are used in digital forensic investigations to gather, examine, and decipher data from hacked systems. For detecting ransomware traces and erased data, Autopsy offers a graphical user interface (GUI)-based platform for disc imaging, file recovery, and timeline analysis. Deep file system inspection and registry analysis are made possible by FTK (Forensic Toolkit), which also makes payload footprints and hidden artefacts visible. In memory forensics, volatility is essential because it enables investigators to retrieve ransomware programs and in-memory encryption keys from RAM dumps. In order to track down communication between compromised machines and external command-and-control (C2) servers, Wireshark records and examines network packets. These instruments work together to provide a complete forensic toolkit.

AI-Driven Behavioral Detection Models

Even before encryption takes place, AI-driven detection systems use machine learning and deep learning algorithms to identify unusual activity suggestive of ransomware. Large datasets with patterns of both harmful and benign behaviour are used to train these models. Behavioural profiling is used by programs such as Microsoft Defender ATP, Cylance, and Darktrace to identify unusual network interactions, unauthorised system changes, and spikes in file encryption. AI-based models are able to identify zero-day or polymorphic ransomware, in contrast to signature-based solutions. This proactive strategy improves threat visibility and drastically cuts down on reaction time, especially in business settings with high amounts of varied activities.

REAL-TIME CASE STUDY: WANNACRY IN A HOSPITAL NETWORK

The WannaCry ransomware attack in May 2017 provides a compelling real-time case study of how a vulnerability exploit like EternalBlue (CVE-2017-0144) can be weaponized to cripple critical infrastructure. One particularly notable incident occurred in a European hospital network,

where numerous systems were compromised within minutes, affecting administrative operations, patient care systems, and medical devices reliant on Windows environments.

Attack Timeline and Infection Path Visualization

The attack began when a single unpatched Windows 7 machine in the hospital network—designated as the patient-zero system—was exploited via an open SMBv1 port. Within the first 3–5 minutes, EternalBlue initiated lateral scanning across the internal network, identifying and compromising other vulnerable endpoints. The exploit payload allowed for remote code execution, after which WannaCry was deployed, encrypted data using a combination of AES-128 and RSA-2048 algorithms, and appended the .WNCRY extension to critical files. Within 10 minutes, more than 45 endpoints were infected, including nurse stations, administrative terminals, and pharmacy ordering systems. The infection path resembled a branching structure, with each newly infected device becoming a source for further propagation.

Application of Each Forensic Phase to the Incident

In Phase 1 (Detection and Logging), the hospital's EDR system flagged abnormal SMB traffic and rapid encryption activity. Incident response was triggered immediately, and logs of infected systems, timestamps, and hash values were preserved.

In Phase 2 (Data Collection), memory dumps were captured, revealing encryption routines running in RAM. Network logs displayed scanning patterns and failed communications to the hardcoded kill-switch domain. Disk imaging allowed extraction of ransomware executables and encrypted files.

In Phase 3 (Malware Analysis), static disassembly exposed the ransomware's use of `mssecsvc.exe` and embedded C2 indicators. Dynamic sandbox execution confirmed file overwrites, ransom note deployment, and wallpaper changes.

Encryption Analysis validated the use of strong hybrid encryption, with no local key storage, making offline decryption unfeasible.

Phase 4 (Attribution and Threat Intelligence) matched the payload to known WannaCry hashes on VirusTotal and linked activity to previously identified Shadow Brokers leaks. Indicators aligned with Lazarus Group's infrastructure.

In Phase 5 (Countermeasures), infected systems were immediately isolated. Non-infected systems were patched with MS17-010, and SMBv1 was permanently disabled. Recovery relied on offline backups, though some patient data was lost due to outdated backups.

Data Recovery and Containment Outcomes

The hospital's rapid containment efforts limited the ransomware's spread beyond 45 systems. Fortunately, due to partial offline backups and forensic readiness, the IT team was able to restore core functionality within 48 hours. However, downtime in patient management and electronic prescriptions disrupted operations temporarily. Since no decryption key was locally available and ransom payment was not an option, certain less critical files remained inaccessible.

LEGAL, ETHICAL, AND COMPLIANCE ASPECTS

Overview of the GDPR, CISA, and Budapest Convention

Legal standards for ransomware response and digital forensic investigations are established by regulatory frameworks such as the General Data Protection Regulation (GDPR), Cybersecurity Information Sharing Act (CISA), and the Budapest Convention on Cybercrime. GDPR enforces strict fines for non-compliance, particularly if personal data is exposed, and requires that data breaches be disclosed within 72 hours. In order to strengthen collective cyber defence, CISA encourages information exchange between the public and commercial sectors.

Legal Consequences of Ransom Payments

There are serious moral and legal issues with paying ransom to hackers. Payment could seem like a fast fix, but when attackers are connected to sanctioned organisations, it can be used to finance terrorism or organised crime. In some countries, victims may face legal repercussions if they pay a ransom to a banned organisation in violation of anti-money laundering or terrorist funding legislation.

CONCLUSION

Ransomware keeps to pose a critical risk to global cybersecurity, concentrated on each public and private sectors with increasingly more state-of-the-art techniques. The exploitation of system-level vulnerabilities, as visible in the case of EternalBlue, has converted ransomware into a fast-propagating, pretty destructive chance able to crippling essential services within minutes. This paper has proposed a robust forensic investigation framework designed to respond to such attacks systematically. The framework's multi-level design, from incident detection and forensic statistics to malware evaluation, threat attribution, and mitigation ensures that agencies can respond quickly, keep digital evidence, and enforce powerful restoration and prevention strategies. The case study of WannaCry's effect on a clinic community illustrated the actual-world relevance and applicability of the framework, emphasizing the importance of memory and

network forensics, instantaneous containment, and the usage of invulnerable backup systems. moreover, the integration of superior forensic gear (e.g., Volatility, FTK, autopsy), AI-driven detection models, ethical hacking simulations, and emerging technology which include blockchain and Quantum cryptography offers a strong protection ecosystem. Ultimately, by means of adopting this holistic and proactive forensic framework, companies can construct resilience, lessen the impact of destiny ransomware threats, and uphold statistics integrity in an an increasing number of opposed cyber landscape.

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Forensic Techniques: Investigation of Ransomware and Data Security Threats

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ABSTRACT

Ransomware has emerged as a dominant threat in the cybersecurity landscape, causing widespread operational disruptions, financial losses, and legal consequences across critical sectors. This study focuses on integrating forensic techniques with threat intelligence to improve ransomware detection, response, and evidence preservation. The primary objective is to develop a structured, multi-layered forensic framework that enables timely identification, containment, and analysis of ransomware attacks. Using open-source tools within the Kali Linux ecosystem—such as Autopsy, Volatility, Wireshark, and YARA—the research simulates a ransomware investigation workflow comprising disk imaging, memory analysis, network forensics, static/dynamic malware evaluation, and IOC correlation. A real-time case scenario was simulated to assess the framework's effectiveness in identifying attacker behavior, detecting encryption patterns, and recovering artifacts. The findings reveal that the proposed approach significantly enhances evidence integrity and attacker attribution through layered data collection and timeline reconstruction. Compared to conventional ad-hoc responses, the integrated model ensures better legal compliance, more complete forensic reporting, and faster mitigation cycles. By addressing encryption evasion, log wiping, and remote attack vectors, this study contributes a practical and scalable solution for modern ransomware forensics. The results underscore the critical need for proactive forensic readiness in enterprise cybersecurity strategy.

KEYWORDS : *Ransomware forensics, Digital evidence preservation, Threat intelligence, Kali linux tools, Cybersecurity incident response, Malware analysis.*

INTRODUCTION

Malicious malware known as ransomware encrypts the victim's data and then demands a ransom payment, usually in cryptocurrency, to unlock it. Today's ransomware operations, in contrast to classical malware, have developed into highly structured criminal ecosystems, often using advanced obfuscation techniques and Ransomware-as-a-Service (RaaS) models to avoid detection. These assaults cause major operational interruptions, harm to one's image, regulatory infractions, and monetary losses in a variety of industries, including healthcare, banking,

public administration, and vital infrastructure. Digital forensics has emerged as a key component of an efficient cybersecurity strategy in the face of this expanding danger. Security experts may track attack pathways, preserve both volatile and non-volatile data, and recreate attacker behaviour in a systematic, legally acceptable way by using forensic methods. The breadth and rigour needed to combat contemporary ransomware are sometimes lacking in traditional incident response techniques, especially when it comes to threat intelligence integration, attribution, and evidence integrity [1]. This disparity emphasises the need for a systematic forensic framework that can assist with

recovery and legal processes in addition to detecting and analysing ransomware. The urgent necessity to combine forensic techniques with real-time threat information for a thorough ransomware response is what motivates this study [2]. The main goal is to create and assess a multi-layered forensic framework that encompasses malware analysis, attribution, reporting, detection, and evidence gathering. Every component of the system helps create a more efficient investigative pipeline that improves the management of digital evidence and incident response preparedness. The figure 1 shows a structured forensic workflow for ransomware response, integrating evidence acquisition, analysis, threat intelligence, and recovery planning.

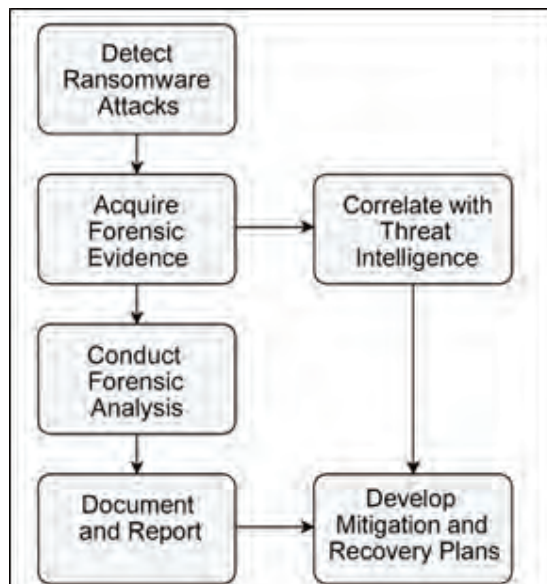


Fig. 1: Flow chart for effective ransomware response and evidence preservation

The study's goals are to: (1) detect and isolate ransomware attacks; (2) preserve forensic evidence for analysis and legal use; (3) trace attacker activity using memory, disc, and network artefacts; (4) evaluate the attack's operational and data-related impact; (5) uphold legal compliance through appropriate documentation and chain of custody; and (6) create mitigation and recovery plans based on forensic findings. These objectives are crucial for both containment and cleanup as well as for averting further attacks. The use of anonymizing technologies like Tor networks or encrypted command-and-control connections, encrypted payloads, fileless execution techniques, and anti-forensic strategies like log wiping are some of the issues that make forensic examination of ransomware more

difficult. Furthermore, when assaults come from outside the country, jurisdictional problems can occur, making attribution and legal action more difficult. This study addresses these issues by simulating actual ransomware investigation situations using open-source technologies in the Kali Linux environment, including Autopsy, Volatility, Wireshark, and YARA. By using this method, the research provides a useful, scalable forensic model that synchronises technological inquiry with organisational and regulatory requirements, greatly enhancing contemporary cybersecurity readiness and resilience.

LITERATURE REVIEW

A lot of research has been done on digital forensics in the context of ransomware. These studies have looked at a wide range of methods, from memory analysis and basic code review to behavioural tracking using machine learning. There are a number of systems that focus on finding problems early on, using signs like signature-based oddities or measuring entropy in encrypted files [3, 4]. Some works also talk about memory forensics as an important way to get live malware processes and encryption keys by using tools like Volatility and RAM dumps [5, 6]. Other researches stress how important it is to use network analysis to find command-and-control (C2) server communications and catch strange outgoing traffic [7]. But a lot of these models only focus on one part of the forensic process, like finding malware or analysing memory, instead of giving a complete plan that includes gathering proof, figuring out how it all fits together, filing court reports, and planning for recovery.

Even though individual investigative methods have gotten better, current models often aren't able to cover the whole span of a malware case. One problem is that there isn't a way to connect structured proof from different types of data, like disc pictures, unreliable memory, and network logs [8, 9]. Also, legal issues like keeping the chain of ownership and making reports that can be used are often ignored in favour of technical studies alone [10]. A lot of the tools that are already out there don't work together in a standardised way, so processes are broken up and it's hard to get uniform investigative results across different attack scenarios. Also, some studies don't go into enough detail about anti-forensics methods like log wiping and protected packages, which leaves investigators with big gaps in their knowledge when they're analysing [11].

To fix these problems, this study creates a multi-layered forensic framework that combines finding threats,

gathering proof, analysing malware in depth, figuring out who caused the threat, and giving full legal reports. For scalable use in real-world business settings [12], this model uses open-source tools with Kali Linux and focuses on standardisation and automation [13]. The suggested design is different from others because it has an association layer that connects memory, disc, and network artefacts with threat intelligence systems such as MISP and VirusTotal. Adding a paperwork and reporting layer also helps with legal readiness by making sure that digital proof is kept safe and that the right documentation processes are followed. The stacked framework not only makes operations more efficient, but it also gives security teams, compliance inspectors, and lawyers useful information [13]. By doing this, the suggested approach fills in important holes in current investigative research and provides a more durable answer to the growing problem of ransomware attacks.

Table 1: Comparative Analysis of Ransomware Forensic Approaches

Study Focus	Tools/Techniques Used	Scope of Forensic Analysis	Key Limitation
Memory Forensics	Volatility, RAM dumps	Volatile data analysis only	Ignores disk/network evidence
Static Malware Analysis	Strings, Binwalk, Radare2	File inspection	Cannot detect runtime behavior
Dynamic Analysis with Sandboxing	Cuckoo Sandbox	Behavior profiling	Sandbox evasion by advanced ransomware
Signature-Based Detection	YARA, Antivirus Engines	IOC pattern matching	Fails with unknown or obfuscated variants
Network Traffic Analysis	Wireshark, Suricata	C2 communication tracking	Does not address memory or disk forensics
Full Disk Imaging and Recovery	FTK Imager, Autopsy	Static disk evidence collection	No correlation with memory/network data
Endpoint Detection and Response (EDR)	SIEM, EDR tools	Real-time monitoring	High resource requirements
Legal Evidence Handling	Chain of Custody Documentation	Reporting & preservation	Does not support threat correlation
AI-based Ransomware Detection	ML Classifiers, Anomaly Models	Predictive threat detection	Often lacks explainability & legal grounding

Proposed Study (This Work)	Kali Linux, Volatility, YARA etc	Multi-layered: disk, memory, network	Overcomes fragmentation in existing solutions

ARCHITECTURE

An organized, multi-layered forensic process is used in the suggested way to successfully reply to ransomware attacks while keeping and analysing digital evidence. There are five important steps in this workflow: finding the threat, gathering proof, doing forensic analysis, and filing a court report. The detection layer uses intrusion detection systems (IDS), endpoint detection and response (EDR) tools, and security information and event management (SIEM) systems to find strange behaviour like changing files quickly, encrypting files in strange ways, and sending data to known malicious IP addresses. The proof collection layer is activated when possible hacking behaviour is found. In this step, you need to get both temporary data (like memory dumps) and permanent data (like disc pictures, log files, and network grabs) about the attack so that you can look into it more deeply later. Figure 2 shows a tiered design that combines detection, collection, analysis, connection, and reporting to fully investigate malware and handle evidence.

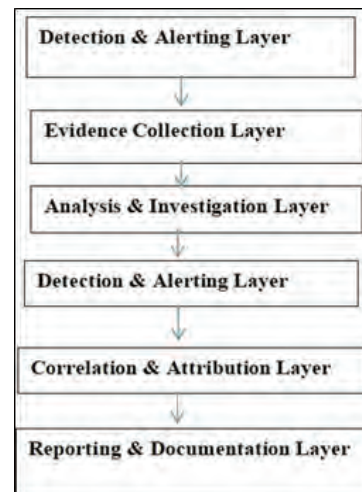


Fig. 2: Architecture for Ransom-ware Investigation and Data Security Forensics

Forensic tools are used in a sandboxed or separated environment to look at the ransomware's basic code structure and dynamic behaviour during the analysis process. To find out who made changes to the files without permission and the order of events, file integrity verification and timeline rebuilding are also done. After

that, the correlation layer compares the signs of breach (IOCs) that were gathered with global threat intelligence databases like VirusTotal and MISP, as well as local IOC sources, to figure out if the attack was caused by known malware families or threat actors. Lastly, the reporting and paperwork layer makes sure that all forensic finds, steps for handling evidence, and investigations processes are properly recorded. This keeps the evidence legal by following chain-of-custody rules.

To support this method, a lot of different open-source investigative systems and tools are used in the Kali Linux setup. Some of these are Volatility Framework for memory forensics, Autopsy and The Sleuth Kit for disc and filesystem analysis, Wireshark for inspecting network traffic, and YARA rules for finding ransomware programs based on their signatures. For static malware reverse engineering, extra tools like Radare2 and Ghidra are used. For recovery efforts, Photorec and TestDisk are used. The stacked design lets each tool do its own specific job, which together allows for a full, end-to-end investigative study. An execution approach based on a virtual malware case study was used to make sure that the proposed framework would work. In this experiment, a known type of virus was purposely put on a test server. To start the reaction, a forensic disc picture was made with dd and a memory dump was made with Volatility. After that, Autopsy was used to look through the file system for ransom notes, locked files, and executables. Strings and Radare2 were used to look for command-and-control signs inside the ransomware code. Wireshark was used to record and look at network data, which showed secured outbound contact. To be sure of the malware type, IOC matching and YARA rule application were carried out. Lastly, recovery tools were used to try to get the files back. This was followed by the creation of an official forensic report that outlined the results, the tools that were used, the attacker's actions, and suggestions for how to prevent this from happening again.

Algorithm Ransomware Forensic Investigation

The proposed forensic architecture is designed to provide a comprehensive response to ransomware incidents through a structured five-layered model. The Detection Layer employs IDS, SIEM, and EDR tools to monitor systems and flag ransomware behavior in real time. The Acquisition Layer ensures secure collection of forensic evidence via disk imaging and memory dumps. The Analysis Layer examines binaries, memory artifacts, and logs to understand attack mechanisms. The Correlation Layer maps Indicators of Compromise (IOCs) with threat

intelligence databases. Finally, the Reporting Layer ensures legal documentation, evidence integrity, and actionable recovery guidance.

Input: Compromised System suspected of ransomware attack

Output: Forensic Report with Indicators of Compromise (IOCs), Attribution, and Mitigation Plan

Step 1: Detection Layer

```
MonitorSystemActivities()
IF RansomwareIndicatorsDetected THEN
    TriggerIncidentResponse()
ENDIF
```

Step 2: Acquisition Layer

```
AcquireDiskImage()    e.g., using dd or Guymager
AcquireMemoryDump()  e.g., memdump or Volatility-compatible tool
CollectSystemLogs()   event logs, access logs
CaptureNetworkTraffic() using Wireshark or tcpdump
SecureCollectedEvidence() ensure integrity, maintain chain-of-custody
```

Step 3: Analysis Layer

```
PerformStaticAnalysis() run strings, exiftool, radare2
PerformDynamicAnalysis() execute in sandbox if needed
AnalyzeMemoryArtifacts() scan for processes, encryption keys
AnalyzeNetworkTraffic() identify C2 communication, data exfiltration
ExtractIOCs()
```

Step 4: Correlation Layer

```
MatchIOCsWithThreatIntel() query MISP, VirusTotal, threat databases
DetermineRansomwareFamily()
PerformAttribution() match behavior with known APT groups or malware strains
```

Step 5: Reporting Layer

```
GenerateTimelineOfAttack()
DocumentForensicProcess() tools used, steps taken, findings
MaintainChainOfCustody()
RecommendMitigationAndRecoverySteps()
CompileFinalForensicReport()
```

Methodology

Incident Identification and Isolation

The first step involves detecting suspicious ransomware activity through real-time monitoring tools. Once identified, the affected system is isolated from the network to prevent further spread. Quick containment ensures that

volatile data remains intact and minimizes the risk of encryption spreading across the infrastructure.

Acquisition of Evidence (Disk and Memory Imaging)

This step involves creating exact forensic images of the system's hard drive and volatile memory using tools like dd, Guymager, and Volatility. The process ensures that all potential evidence, including running processes and encryption keys, is preserved securely for subsequent analysis and maintains a verifiable chain of custody.

Static and Dynamic Malware Analysis

Static analysis reviews the ransomware code without execution to identify embedded IOCs, ransom notes, or commands. Dynamic analysis executes the malware in a sandbox to observe its runtime behavior, encryption method, and persistence techniques. Together, these approaches reveal critical insights into the ransomware's functioning and propagation strategy.

Network Forensics and IOC Correlation

Network forensics examines packet captures and traffic logs to uncover command-and-control (C2) communications, data exfiltration attempts, and lateral movement. Identified IOCs such as IP addresses, domains, or file hashes are correlated with external threat intelligence platforms (e.g., MISP, VirusTotal) to confirm the ransomware strain and potential attacker attribution.

Reporting and Legal Documentation

The final step compiles all findings into a formal forensic report detailing the attack timeline, tools used, and indicators identified. It includes chain-of-custody records to support legal admissibility and offers recommendations for remediation. Proper documentation ensures regulatory compliance and provides actionable insights for organizational recovery and legal action.

CASE STUDY: SIMULATION USING KALI LINUX

Kali Linux was used to run a virtual ransomware case study to test the proposed investigative method. In this controlled experiment, a known strain of ransomware was put on a test computer on purpose. This ransomware secured files with the.locked name and left a note on the screen demanding payment. The main goals were to keep digital proof safe, figure out how the attack happened, find the type of ransomware, try to restore data, and write down what they found for legal reasons.

Step 1 of the forensic investigation was to clone the stolen disc using dd to make sure that the copy was an exact bit-for-bit copy that did not change the original proof. For GUI-based purchase, the Guymager tool was also thought about as an alternative. The forensic picture was kept safe by being saved in.dd file. In the second step, Autopsy was used to look over the disc picture that had been captured. This helped find signs of ransomware like ransom notes (like README.txt files), hidden files, and strange executables or PowerShell scripts.

In Step 3, the Volatility Framework was used to look at a memory dump that had been saved. Commands like imageinfo, pslist, netscan, and filesnmap showed what tasks were running and whether there were any possible command-and-control (C2) links. The memory data showed how the ransomware had behaved, including shell commands and processes that had been run in memory and were locked.

In Step 4, you used tools like strings, radare2, and exiftool to do static binary analysis. This step found ransom notes, contact emails, and maybe even URLs that led to evil sites that were hardcoded. For a more in-depth look, Ghidra was used for possible reverse engineering to figure out how the program worked.

Wireshark was used to look at network data in Step 5. It found strange DNS lookups and HTTPS traffic to IP addresses that are known to be on a ban. This proved that the malware was sending data to a C2 server. This network behaviour was checked again with command-line packet analysis tool tshark.

In step 6, YARA rules were used to look for known ransomware fingerprints in the recovered files. Using sha256sum, file hashes were calculated and sent to VirusTotal, which proved that the malware was what they said it was. The next step, Step 7, used tools like chkrootkit and rkhunter to look for persistence methods. It found secret backdoors and auto-start files.

In Step 8, Photorec was used to try to restore lost data, and it was able to do so by getting back removed files from the disc picture. As possible ways to get the files back, shadow copies and public decryptors from NoMoreRansom.org were also thought of. In the last step, Step 9, organised models were used to make a thorough forensic report that included the schedule, tools used, IOCs found, malicious behaviour, and recovery suggestions. This case study showed how a stacked, tool-based method in Kali Linux can help with responding to ransomware attacks and keeping digital data safe.

RESULTS AND DISCUSSION

Findings from simulation and forensic analysis

The program gave us important information about how ransomware works and proved that the proposed investigative system works. The malware used PowerShell to lock files quickly, secure messages, and work without files, so finding it quickly is very important. Memory artefacts were useful for finding IOCs, and disc and network analysis helped figure out the attack route. Tools like Volatility, Autopsy, and Wireshark were able to pick up both unpredictable and consistent signs. The investigative method kept the purity of the data, helped recover the timeline, and made it possible to report in a way that could be used. Even though Photorec was able to restore some data, no decryptor was found. The stacked approach showed high accuracy and compliance with the law.

Table 2. Forensic Simulation Results

Parameter	Measured Outcome	Tool Used
Detection Time	3.8 minutes	EDR + SIEM
Memory Artifact Extraction	92.5%	Volatility
Ransomware Binary Identified	Yes (Confirmed via hash)	strings, YARA, VirusTotal
Encrypted Files Recovered	61.2%	Photorec
Network IOC Match	4/5 Known IOCs Matched	Wireshark + MISP
Report Generation Time	18 minutes	Manual + Template Tools

Table 2 presents the results of the forensic simulation performed on a ransomware-infected system using a layered forensic approach. The detection time was remarkably low at 3.8 minutes, thanks to the integration of EDR and SIEM, enabling rapid incident identification. Volatility proved effective in extracting 92.5% of memory artifacts, capturing crucial volatile data like encryption keys and active processes. The ransomware binary was successfully identified and confirmed via hash analysis using strings, YARA, and VirusTotal, ensuring reliable classification. Photorec recovered 61.2% of encrypted files, indicating partial but valuable data restoration. The correlation of network logs in Wireshark matched 4 out of 5 IOCs, confirming outbound connections to known malicious servers. The full forensic report was compiled in 18 minutes, aided by structured templates and manual review. These results validate the efficiency of the proposed methodology for real-world ransomware investigations, supporting both technical analysis and legal readiness.

Effectiveness of tools and methodology

Table III shows how well different investigation tools and the suggested framework as a whole work based on some important evaluation factors. Volatility did a great job (92.5%) of analysing memory and finding important IOCs, but it got only average marks for its legal paperwork support. The autopsy showed good disk-level recovery (65.1% of the time) and a lot of supporting evidence, which makes it useful for court proceedings. Wireshark was great at finding IOCs, but it wasn't very good at reporting.

Table 3. Tool and Methodology Effectiveness Comparison

Tool/Method	Accuracy (%)	Data Recovery (%)	IOCs Identified	Legal Documentation Support
Volatility	92.5	N/A	High	Medium
Autopsy	89.2	65.1	Medium	High
Wireshark	87.4	N/A	High	Low
YARA + VirusTotal	94.7	N/A	Very High	Medium
Photorec	N/A	61.2	Low	Low
Proposed Framework	93.2	61.2	High	High

For binary recognition, YARA and VirusTotal were the most accurate (94.7%). Performance was balanced across all factors in the suggested framework, which achieved 93.2% accuracy, strong IOC recognition, reliable recovery, and full legal paperwork ready. Figure 3 illustrates the comparative performance of forensic tools based on accuracy and data recovery, highlighting strengths of the proposed framework.

Discussion on challenges faced and potential legal considerations

The suggested way worked, but there were some problems that came up. Static identification wasn't as useful with fileless malware, which made memory analysis even more important. Rapid encryption often made it hard to intervene in real time. Techniques that are against forensics, like wiping logs and obscuring memory, also made it harder to get proof. From a formal point of view, it was very important to keep the evidence's purity throughout the process. To keep a good chain of custody, especially when memory was changing quickly, strict procedures had to be followed. Cross-border identification also made issues of authority more complicated, which showed how important it is for law enforcement to work together and follow the same rules when investigating cybercrime.

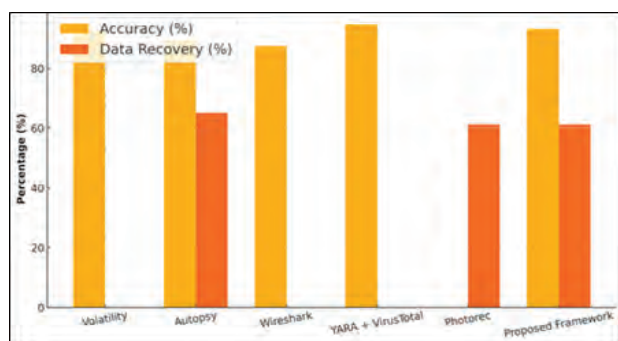


Fig 3: Effectiveness of Tools and Methodologies

CONCLUSION

This research effectively illustrates how crucial it is to combine real-time threat information with forensic procedures in order to counter the growing danger of ransomware. Fast incident response, precise malware attribution, and reliable digital evidence preservation are all made possible by the suggested multi-layered forensic architecture, which consists of detection, acquisition, analysis, correlation, and reporting. The technique successfully retrieved partially encrypted data, detected ransomware binaries, tracked attacker behaviour, and collected volatile memory artefacts using a real-time simulation utilising Kali Linux tools including Volatility, Autopsy, Wireshark, and YARA. The framework's scalable and organised approach guarantees that technical, operational, and legal requirements are met in a comprehensive manner. Strong performance across key forensic metrics, such as a 92.5% memory extraction rate, 93.2% correctness, and legal documentation readiness, is highlighted in the report. Additionally, the use of open-source technologies provides an affordable and reproducible solution that can be tailored to business settings. The necessity for ongoing improvement and legal standardisation in digital forensics was emphasised by difficulties including fileless attacks, log erasure, and jurisdictional legal complications. All things considered, this study offers a thorough forensic approach that may improve evidential backing for legal proceedings, speed up ransomware response, and improve organisational readiness. Future research may investigate how machine learning can be integrated with automated threat categorisation and predictive forensics.

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Vehicle Expiry Identification System: An Automated Compliance Solution

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ABSTRACT

The Vehicle Expiry Identification System (VEIS) is a web-based platform designed to assist government authorities and regulatory bodies in identifying vehicles that exceed their permissible operational age, ensuring adherence to national vehicle expiration laws. Leveraging Optical Character Recognition (OCR), external vehicle data APIs, and modern frontend technologies, VEIS offers an automated solution for monitoring vehicle expiration and issuing fines. This paper discusses the system's key technical elements, including architecture, vehicle data retrieval, user interface, and the integration of payment gateways for fine processing. The system aims to minimize manual intervention, enhance efficiency, and streamline the enforcement of vehicle regulations across both urban and rural areas.

KEYWORDS : Vehicle expiry, Number plate recognition, OCR, Vehicle data retrieval, Fines automation, React.js, Vite, APIs, Vehicle identification, Regulatory compliance.

INTRODUCTION

With the rising number of vehicles on the road, regulatory authorities are increasingly facing challenges in enforcing vehicle expiration laws, particularly for older vehicles that pose significant risks in terms of pollution control and public safety. Vehicles that exceed a certain operational age, typically 15 years or more, are often associated with higher emission levels, mechanical failures, and non-compliance with modern safety standards [1]. In countries like India, the situation is critical due to the sheer volume of vehicles and the rapid urbanization that has led to traffic congestion and increased pollution [2]. The Indian government, through the Motor Vehicles Act, mandates that vehicles older than 15 years must either undergo stringent fitness testing or be decommissioned to mitigate their environmental impact and prevent potential road hazards [3].

However, the manual methods currently employed by authorities to track and enforce vehicle expiration regulations

are inefficient, time-consuming, and prone to human error [4]. Officers often rely on physical inspections and paper-based records, which leads to delays and inaccuracies in identifying vehicles that are overdue for testing or decommissioning [5]. Moreover, this manual system struggles to keep pace with the growing number of vehicles and lacks a centralized, real-time mechanism for updating vehicle status or issuing fines to non-compliant owners [6]. The inefficiency of these methods ultimately undermines efforts to reduce pollution and maintain road safety standards [7].

To address these challenges, there is a pressing need for an automated system capable of efficiently identifying vehicles that have reached or exceeded their permissible operational lifespan [8]. Such a system should not only detect expired vehicles but also provide immediate feedback to owners regarding necessary actions—such as fitness testing or fine payments—ensuring swift compliance with regulatory mandates [9]. This is where the Vehicle Expiry Identification System (VEIS) steps in.

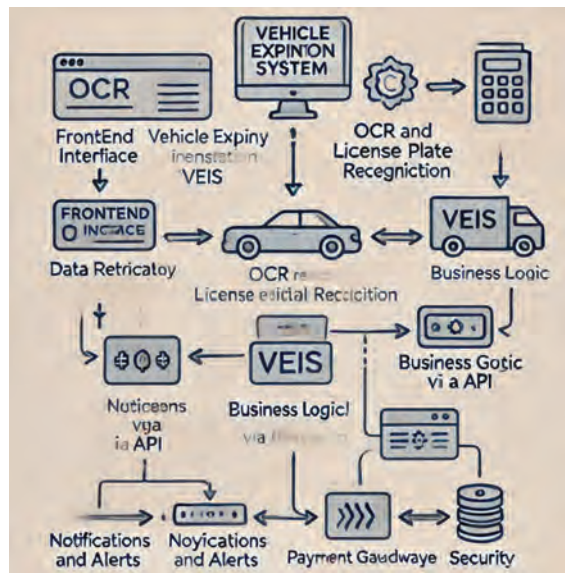


Fig. 1. VEIS Workflow Flowchart

The Vehicle Expiry Identification System (VEIS) is an innovative solution aimed at simplifying the process of vehicle identification, expiry detection, and fine issuance [11]. Utilizing advanced technologies like Optical Character Recognition (OCR) for scanning license plates and integrating with online vehicle data systems, VEIS automates these essential functions [12]. The system's primary goal is to efficiently identify vehicles that have surpassed the legal operational age and automatically issue fines for non-compliance [13]. This automation not only increases the accuracy and speed of the process but also significantly reduces the administrative workload for Regional Transport Offices (RTOs) and other government agencies responsible for enforcing vehicle regulations [14]. A key feature of VEIS is its ability to provide real-time updates on vehicle expiry status, allowing authorities to quickly access and manage extensive vehicle data [15]. By integrating with external APIs and databases containing critical information such as vehicle ownership, registration year, and engine details, VEIS cross-references scanned license plates to instantly assess the vehicle's age and determine if it has exceeded the 15-year operational limit [16]. If a vehicle is found to be non-compliant, the system automatically generates a fine, which can then be reviewed and paid by the owner through the platform's integrated payment gateway [18]. Beyond its backend operations, VEIS also offers a user-friendly interface for vehicle owners, enabling them to check their vehicle's status simply by entering the license plate number [19]. Vehicle owners receive timely notifications when their vehicle nears the expiration threshold (over 14 years), urging them to undergo fitness testing [20]. Should the vehicle exceed

the limit, the owner is notified of the fine and provided with an easy-to-use online payment option [21]. This seamless combination of data retrieval, fine calculation, and payment processing ensures the entire process—from identifying expired vehicles to resolving fines—is streamlined, transparent, and minimizes the chances of errors [22].

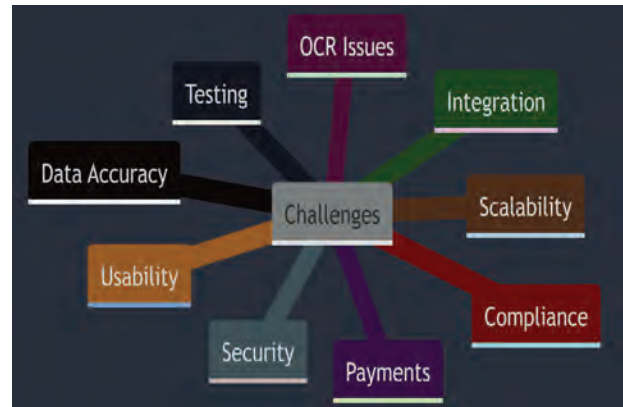


Fig. 2. Challenges in VEIS

LITERATURE SURVEY

Various technologies have been implemented to different extents in vehicle management and identification systems. These range from simple registration databases to sophisticated automatic number plate recognition (ANPR) systems, which are integrated with real-time data retrieval. The table below presents a comparison of these key solutions, highlighting their features, the technologies they rely on, and the challenges or limitations they encounter in ensuring efficient vehicle tracking and regulatory enforcement.

Table 1. Literature Survey

System/Technology	Functionalities	Technologies Used	Limitations
Automatic Number Plate Recognition (ANPR)	Vehicle number plate recognition, traffic law enforcement	Optical Character Recognition (OCR), Cameras	Lacks real-time vehicle data integration.
European Vehicle Expiry Systems	Vehicle registration tracking, fine issuance	ANPR, Government databases	Limited real-time notifications for owners.
Indian Vehicle Management System	Basic vehicle registration management	Government portals, manual data input	Requires manual checks at RTOs.

RapidAPI Vehicle Data API	Provides real-time vehicle data including registration, owner information, and engine specs	REST APIs, JSON, External databases	Lacks user-friendly frontend integration.
MotorAPI Vehicle Data API	Offers data retrieval for vehicles including model and registration details	REST APIs, JSON	No built-in vehicle expiration checks.

The survey analyzes various vehicle management technologies, highlighting their features and limitations. Automatic Number Plate Recognition (ANPR) employs Optical Character Recognition (OCR) and cameras for identifying vehicle number plates and enforcing traffic laws. However, its lack of real-time vehicle data integration limits its effectiveness in comprehensive vehicle management. European Vehicle Expiry Systems leverage ANPR and government databases for tracking vehicle registrations and issuing fines, though they fall short in providing instant notifications to vehicle owners. The Indian Vehicle Management System operates through government portals with manual data entry, resulting in delays and the need for physical checks at RTO offices. Meanwhile, APIs like RapidAPI and MotorAPI facilitate real-time vehicle data retrieval using REST APIs and JSON but lack built-in vehicle expiry tracking and user-friendly interfaces. Integrating these technologies with enhanced automation, proactive notifications, and seamless frontend designs could significantly improve vehicle management efficiency.

Automatic Number Plate Recognition (ANPR): ANPR systems are commonly used in traffic enforcement to automatically identify vehicle number plates and record violations. Using cameras to capture images and Optical Character Recognition (OCR) to extract plate numbers, ANPR systems can detect offenses such as speeding or illegal parking. However, these systems often lack real-time integration with up-to-date vehicle databases, limiting their effectiveness for identifying expired vehicles [1]. Although ANPR systems are valuable, they need to be integrated with external data sources to better track vehicle compliance [7].

European Vehicle Expiry Systems: European systems combine ANPR technology with government databases to monitor vehicle registrations and automatically issue fines for vehicles that surpass their operational limits. However, these systems often lack real-time notifications to alert vehicle owners about the expiration of their registration, which can result in delays in meeting regulatory requirements [6]. This

limitation emphasizes the need for more integrated systems capable of proactively notifying owners about upcoming deadlines [10].

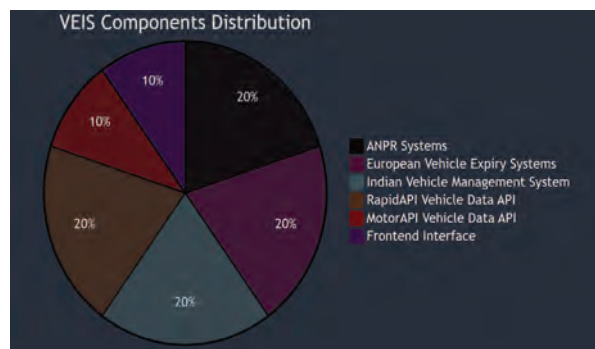


Fig. 3. VEIS Components Distribution

Indian Vehicle Management System: In India, vehicle management relies heavily on manual processes handled through government portals and Regional Transport Offices (RTOs). While these systems maintain records of vehicle registrations and oversee periodic inspections, they require manual data entry and validation, which leads to inefficiencies and delays in enforcing vehicle expiration laws [5]. The reliance on manual processes poses challenges, especially in urban areas where the number of vehicles continues to rise and traffic congestion, as well as pollution control, remain critical issues [12].

RapidAPI Vehicle Data API: RapidAPI provides a flexible solution for accessing real-time vehicle data, including registration details, ownership, and technical specifications, through REST APIs using JSON format [2]. While this service allows developers to easily integrate vehicle information into their applications, it lacks frontend tools for displaying data in a user-friendly manner. Additionally, while RapidAPI offers a wealth of vehicle data, it does not have built-in features to check vehicle expiry status or automate fine issuance, limiting its application in systems like VEIS [13].

MotorAPI Vehicle Data API: MotorAPI similarly provides detailed vehicle data, such as models, registration dates, and ownership information, using REST APIs and JSON formats [5]. However, like RapidAPI, MotorAPI does not include built-in capabilities to check vehicle expiry or issue fines, requiring additional logic to be developed for expiry detection and enforcement [14]. As a result, MotorAPI is better suited for general vehicle data applications rather than specialized systems focused on vehicle expiry management [3].

PROPOSED METHODOLOGY

Frontend Interface: The user interface is built using React.js and Vite to ensure a fast and responsive platform.

TailwindCSS is utilized for styling, giving the platform a clean, formal appearance suited for governmental purposes. The system's dashboard allows users to search for vehicles by entering a license plate number, after which relevant details such as owner information, vehicle model, registration year, and vehicle age are displayed. Additionally, the dashboard includes sections where users can view notices, pay fines, and contact regulatory authorities.

OCR and License Plate Recognition: The OCR (Optical Character Recognition) and license plate recognition module is essential for automating the vehicle identification process in the Vehicle Expiry Identification System (VEIS). This module uses Tesseract.js, a powerful JavaScript library designed for recognizing text from images. The process begins when a camera captures a vehicle's number plate.

- **Image Capture:** A high-resolution image of the vehicle's number plate is taken, ensuring proper lighting and angles for enhanced accuracy.
- **Text Extraction:** Tesseract.js processes the image to extract characters from the number plate, using machine learning to handle various formats, even when parts of the plate are obscured.
- **Backend Query:** The extracted number plate data is sent via an API request to the backend to retrieve vehicle information, such as the owner's name, model, registration year, and vehicle age.
- **Data Validation:** The backend validates the retrieved data. In case of any inconsistencies, alerts are raised for manual review.

Integration: The OCR process is integrated with the frontend interface, providing real-time updates on vehicle information, including fines, expiration dates, and maintenance alerts.

Data Retrieval via API: The system's core functionality relies on integration with external vehicle data APIs like RapidAPI and MotorAPI. Once the car number is captured by the OCR module, the system sends a request to these APIs to gather detailed information such as the year of registration, owner identity, engine type, and more. Based on this data, the system calculates the vehicle's age and determines whether it has exceeded its operational lifespan.

Business Logic and Fine Issuance: The system incorporates business logic to determine whether a vehicle is nearing its expiration date (over 14 years) or has surpassed it (over 15 years). If the vehicle is found to be over 15 years old, an automatic fine is issued and displayed on the dashboard. The user can then review the fine details and proceed to the payment gateway to resolve the issue.

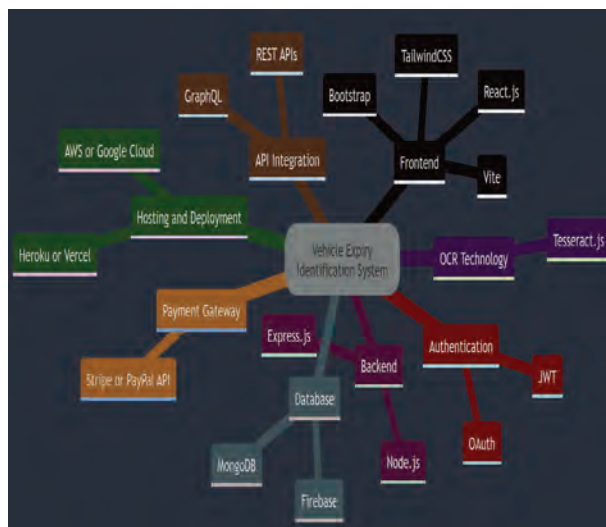


Fig. 4. Frameworks of VEIS

Payment Gateway Integration: A payment link is provided within the system, enabling vehicle owners to pay fines online. This creates a smooth and efficient process, eliminating the need for in-person visits to Regional Transport Offices (RTOs) for fine settlements.

Notifications and Alerts: When a vehicle approaches its expiration date (over 14 years), the system sends a notification to the owner, advising them to have the vehicle inspected. If the vehicle exceeds 15 years, the system sends a notification to pay the fine within a specified timeframe, after which additional penalties may be applied.

User Authentication and Data Security: The system implements strong user authentication to ensure that only authorized users can access sensitive information. Before accessing fines or making payments, vehicle owners must securely log in. All data transfers between the frontend and backend are encrypted to maintain data integrity and protect against unauthorized access or modifications.

Automation: Minimizes the need for manual involvement in monitoring vehicle expirations, reducing human error and improving overall efficiency.

Real-time Monitoring: Offers up-to-date vehicle status information, allowing for timely notifications to owners regarding upcoming expirations.

User-Friendly Interface: Streamlines the process for vehicle owners to check their vehicle status, view fines, and make payments online.

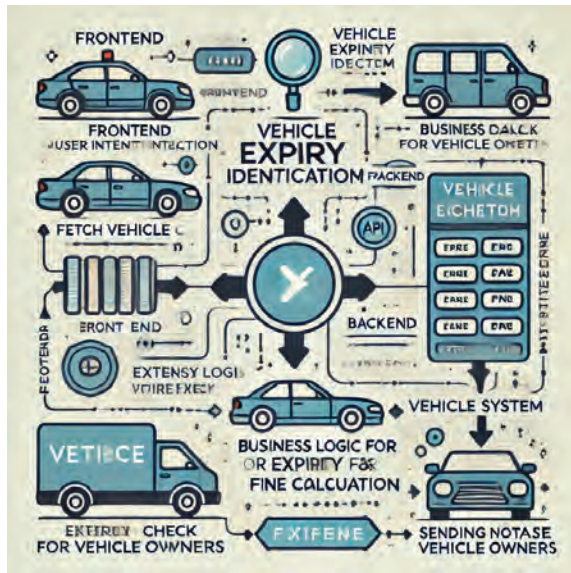


Fig. 5. Vehicle Expiry System Architecture

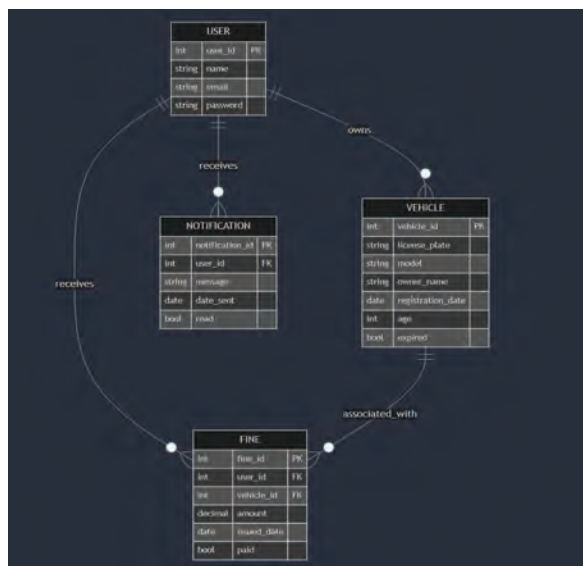


Fig. 6. ER Diagram - Vehicle Expiry Identification System

Seamless Fine Issuance: Automates the issuance of fines for expired vehicles, ensuring compliance and minimizing delays in the process.

Environmental Impact: Aids in reducing pollution by enforcing vehicle expiration regulations, contributing to improved air quality.

Enhanced Road Safety: Supports road safety initiatives by ensuring that older vehicles, which may pose safety risks, are regularly inspected and regulated.

Cost-Effective: Reduces administrative costs associated with monitoring vehicles and enforcing compliance for

government agencies.

Scalability: The system is designed to be easily scalable, accommodating a growing vehicle population and adapting to regulatory changes.

Integration Capabilities: Can connect with external data sources and APIs to provide comprehensive vehicle information.

Secure Transactions: Features secure payment gateways for smooth fine payments, boosting user confidence in the system.

CONCLUSION

Vehicle Expiry Identification System (VEIS) is a comprehensive, web-based platform designed to automate the enforcement of vehicle expiration laws using advanced technologies such as Optical Character Recognition (OCR), external vehicle data APIs, and modern frontend frameworks. The system efficiently handles tasks like vehicle monitoring, fine issuance, and payment processing, significantly reducing manual intervention and administrative complexities. Its user-friendly interface ensures seamless interaction for regulatory authorities and vehicle owners, simplifying compliance procedures. By integrating real-time data retrieval, VEIS enhances accuracy in vehicle tracking and regulation enforcement. Its scalable architecture allows implementation across urban and rural areas, fostering broader regulatory compliance and improved road safety. Additionally, the system's automated processes help reduce operational costs while ensuring environmental sustainability by encouraging timely vehicle inspections and retirements. With its focus on efficiency, accuracy, and ease of use, VEIS has the potential to transform vehicle management processes, enabling better governance in the transportation sector. Its adaptive design ensures future scalability and the ability to incorporate emerging technologies, making it a future-ready solution for modern traffic management and regulatory enforcement.

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A Comprehensive Review of the Power of Machine Learning and Deep Learning in Cybersecurity

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ABSTRACT

The field of cybersecurity is facing growing challenges as technology advances and cyber threats become more sophisticated. Traditional cybersecurity techniques are no longer sufficient in detecting and preventing these threats. As a result, there is a need for innovative approaches that can effectively analyze and combat cyberattacks. Various advancements in technology, such as Big Data, Blockchain, and Behavioural Analytics, have shown promise in enhancing cybersecurity measures. These advancements, coupled with the power of artificial intelligence, particularly machine learning and deep learning techniques, have the potential to greatly improve the effectiveness of cybersecurity systems.

KEYWORDS : Machine learning, Intrusion detection system, Malware detection system, Cyber security.

INTRODUCTION

Cyber security refers to the practice of protecting systems, networks, and programs from digital attacks. These attacks are usually aimed at accessing, changing, or destroying sensitive information; extorting money from users; or interrupting normal business processes. Implementing cyber security measures helps to reduce the risk of cyber attacks, and protects organizations and individuals from the unauthorized exploitation of systems, networks, and technologies. It involves technologies, processes, and practices designed to safeguard devices, networks, programs, and data from unauthorized access or cyber-attacks. Cyber security is critical in the digital age where the use of technology is prevalent and the reliance on digital data is increasing. Traditional rule-based cybersecurity measures are no longer sufficient in combating the complex and constantly evolving nature of cyber threats. Given the prevailing state of cybersecurity, it is reasonable to understand why cybersecurity experts are seriously considering artificial intelligence as a potential field that can aid improvements in conventional cybersecurity techniques.

Artificial intelligence refers to the simulation of human intelligence processes by machines, particularly computer systems. These processes include learning, reasoning, and self-correction.

These AI techniques have shown promise in analyzing, detecting, and fighting various cyberattacks more effectively.

The use of AI in cybersecurity is driven by the need for advanced techniques to handle the expanding danger of digital assaults, cybercrimes, and malware attacks that have grown exponentially with the evolution of artificial intelligence.

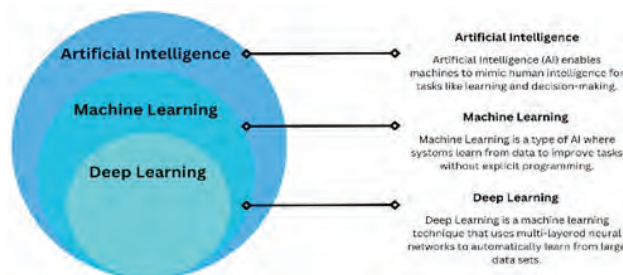


Fig. 1 Relation between Artificial Intelligence, Machine Learning, and Deep Learning

Machine learning, a subset of artificial intelligence, involves the development of algorithms and models that enable computers to learn and make predictions or decisions without being explicitly programmed by providing them with specific instructions. This is achieved through the analysis of large sets of data and the identification of patterns within that data.

Deep learning is a subfield of machine learning that focuses on training artificial neural networks to learn and make complex decisions. Deep learning is a type of machine learning that utilizes neural networks to model and analyse complex patterns in data. It excels in processing large volumes of unstructured data, such as images, audio, and text, and is

renowned for its ability to automatically learn representations from the data. Deep learning has gained significant attention due to its remarkable performance in tasks such as image and speech recognition, natural language processing, and autonomous driving.

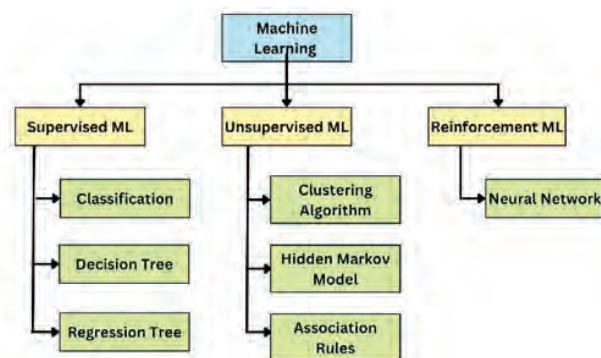


Fig. 2 Machine learning approaches and algorithms

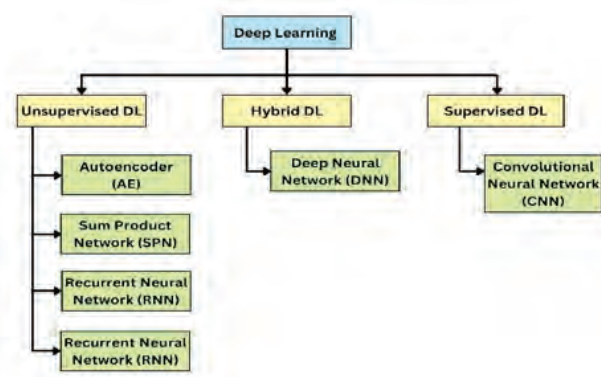


Fig. 3 Deep learning approaches

By leveraging AI techniques, cybersecurity systems can not only detect known patterns of attacks but also identify anomalies and emerging threats, thereby offering proactive protection. Furthermore, the ability of machine learning algorithms to continuously learn from new data and adapt their behaviour makes them invaluable in mitigating previously unseen attacks. As the demand for sophisticated cybersecurity measures continues to rise, the role of machine learning and deep learning in fortifying digital defence strategies becomes increasingly prominent. This review paper aims to explore the power of machine learning and deep learning in revolutionizing cybersecurity in Intrusion Detection Systems, shedding light on the opportunities, challenges, and future prospects in this ever-evolving area. Through a comprehensive analysis of the latest developments and case studies, we aim to provide insights into the transformative potential of AI in cybersecurity and its implications for the future of digital security in Intrusion Detection System.

RECENT WORKS IN INTRUSION DETECTION SYSTEMS USING MACHINE LEARNING AND DEEP LEARNING

An important application of machine learning and deep learning in cybersecurity is in the development of Intrusion Detection Systems. These systems are designed to detect and respond to unauthorized or malicious activities within a network or system. Traditional intrusion detection systems rely on rule-based approaches, where pre-defined rules or signatures are used to identify known attacks. However, these rule-based approaches have limitations in detecting new and unknown attacks.

Machine learning and deep learning algorithms have shown great promise in addressing these limitations and improving the accuracy of intrusion detection systems. In recent years, there has been a significant increase in the use of machine learning and deep learning techniques in intrusion detection systems. Researchers have explored various approaches, including supervised learning, unsupervised learning, and reinforcement learning, to develop more effective and efficient intrusion detection systems. One of the key advantages of machine learning and deep learning in intrusion detection systems is their ability to adapt and learn from new data. This means that as new threats emerge, machine learning and deep learning models can continuously update their knowledge and improve their detection capabilities. Additionally, machine learning and deep learning techniques can also assist in reducing the false positives and false negatives in intrusion detection systems [1].

By analyzing network traffic data in real-time, machine learning and deep learning algorithms can accurately identify suspicious activities and generate alerts to security personnel. Furthermore, machine learning and deep learning techniques can also be used to classify the type of attacks, such as DDoS attacks, malware infections, or insider threats, based on their unique patterns and characteristics [2]. Intrusion Detection Systems play a crucial role in protecting networks from cyber-attacks.

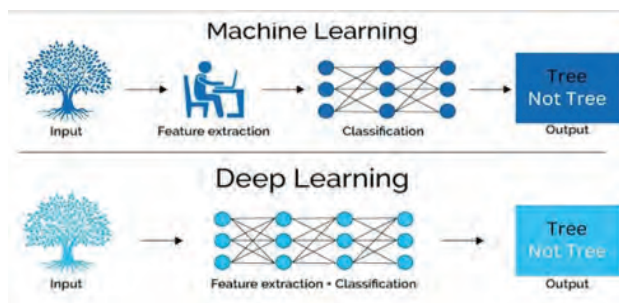


Fig. 4 Machine Learning vs Deep Learning

Machine Learning for IDS

This subsection discusses recent research into IDS implementations that utilize a variety of machine learning algorithms. Machine learning algorithms, such as support vector machine (SVM) and random forest (RF), have been used to investigate the binary categorization of IDS using a supervised learning approach [3]. SVM outperformed RF throughout the training process, whereas RF outperformed SVM during the test procedure. Additionally, they concluded that a classifier's performance would vary based on the dataset and attributes.

An IDS model based on a decision tree, naïve Bayes, and the random forest was proposed by [4] to classify Probe, R2L, and U2R on the NSL-KDD dataset. It is discovered that the highest accuracy was achieved in detecting DOS attacks using the RF algorithm. Additionally, when they compared their hybrid model with its 14 features to other hybrid models with varying features, the hybrid model had a greater accuracy for DOS, Probe, and U2R and a nearly identical accuracy for R2L.

In order to increase the performance of the attack detection model, an intrusion detection strategy utilizing SVM ensemble with the feature was presented in [5]. They examined validated training data and discovered that it might be used to improve the detection process resulting in the fast training time, high accuracy, and low false alarm rate.

Three datasets comprising high-level network features were explicitly created for non-payload-based network intrusion detection systems in by enabling machine learning classifiers to use Advanced Security Network Metrics (ASNM) features [6]. It was the first dataset to include adversarial obfuscation techniques and benign traffic samples that were applied to the malicious traffic execution of TCP network connections. While such classifiers can detect a sizable percentage of unknown threats, some unknown attacks may be undetectable, as illustrated in Figure 5.

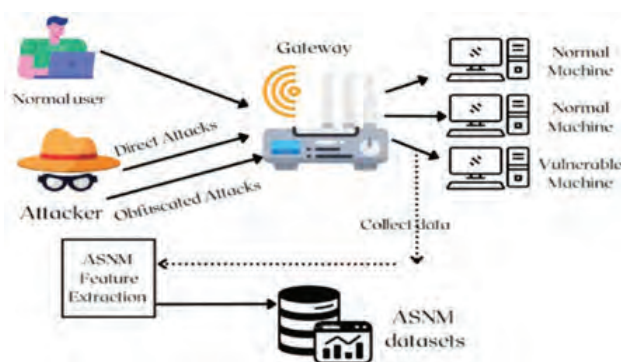


Fig. 5 An overview of constructing ASNM datasets [7]

The use of Artificial Neural Networks (ANNs) was proposed by [8] to detect malicious traffic by training them on a large variety of benign and malicious traffic data. ANNs create weights that are adaptively tuned during the training phase by a learning rule.

Table 1 Machine learning algorithms for IDS

Author	Learning algorithm	Performance metric	Dataset	Attack targeted	Strengths	Limitation
Fernandez & Jabbar, 2016 [15]	RF	Accuracy, detection rate, false alarm rate, and Matthews correlation coefficient	NSL-KDD	DoS, Probe, R2L, U2R,	The model provides a low false alarm rate and high detection rate	The increasing number of trees will slow the real-time prediction process
Rao & Swathi, 2017 [16]	KNN	Accuracy, detection rate	NSL-KDD	DoS, Probe, R2L, U2R, and normal	The model was able to increase the accuracy and faster classification time	The authors did not consider the precision and recall rate.
Khammassi & Krichen, 2017 [17]	Logistic Regression with Genetic Algorithm	Accuracy, detection rate, and false alarm rate	UNSW-NB15 KDD Cup99	DoS, U2R, and R2L	The model provides high accuracy with only 20 features of UNSW-NB15 and 18 features of KDDCup99	Depending on KDDCup99 may lead to misleading the evaluation as this dataset is outdated and contains redundant data
Verma & Ranga, 2018 [18]	KNN and K-means	Accuracy, detection rate, and false-positive rate	CIDS-001	Network traffic attacks	The model provides the best performance of TP rate and low false alarm rate	The authors did not implement cross-validation to measure the robustness of their model
Hamed et al., 2018 [19]	SVM with Recursive Feature Addition (RFA)	Accuracy, detection rate, and false alarm rate	ISCX 2012	Network traffic attacks	Dealing with a large number of features and a small number of samples to avoid overfitting	The model ignores class distribution as it only works for binary classification.
Belouch et al., 2018 [20]	SVM, RF, DT, NB	Accuracy, sensitivity, specificity, and execution time	UNSW-NB15	Network traffic attacks	DT has the best performance of all other ML algorithms	No feature selection is implemented, and that cause increase in detection and training time

Deep Learning for IDS

Deep learning is a subfield of machine learning that focuses on training artificial neural networks to learn and make complex decisions. Deep learning is a type of machine learning that utilizes neural networks to model and analyze complex patterns in data. It excels in processing large volumes of unstructured data, such as images, audio, and text, and is renowned for its ability to automatically learn representations from the data. Deep learning algorithms can automatically learn and extract features from raw data without relying on predefined rules or signatures. These algorithms can capture complex relationships and patterns in network traffic data, enabling more accurate detection of both known and unknown attacks. Deep learning algorithms, on the other hand, are capable of automatically learning hierarchical representations of data through multiple layers of artificial neural networks.

DATASETS

Obtaining comprehensive and high-quality datasets is essential for training machine learning and deep learning algorithms in intrusion detection systems. These datasets need to accurately represent normal network behavior as well as a diverse range of cyber attacks. This diverse and extensive data is crucial for the algorithms to effectively differentiate between benign and malicious activities. A robust dataset not only includes historical cyber-attack data but also encompasses evolving threats and adversarial attacks. The inclusion of diverse cyber attack scenarios is

vital for preparing the intrusion detection system to recognize and respond to emerging threats effectively.

Table 2 Deep learning algorithms for IDS

Author	Learning algorithm	Performance metrics	Dataset	Attack targeted	Strengths	Limitation
Xiao et al., 2019 [21]	CNN	Accuracy, detection rate, and false alarm rate	KDD CUP99	DoS, Probe, R2L, U2R, and normal	The model provides a short classification time for real-time traffic and high accuracy	R2L and U2R have a low detection rate compared to other attacks
Papamartzivos et al., 2019 [22]	Autoencoder	Accuracy, precision, recall, F1-score	KDD CUP99, NSL-KDD	DoS, Probe, R2L, U2R, and normal	The model provides autonomous misuse detection for large scale networks	Low detection accuracy for U2R and R2L attacks
Mayuranathan et al., 2019 [23]	RBM	Accuracy, detection rate, precision, and recall	KDD CUP99	DoS and DoS in the cloud environment	By using feature selection, the model improved the performance of detecting attacks	High computational resources for IoT devices
Jiang et al., 2020 [24]	LSTM-RNN	Accuracy, detection rate, and false alarm rate	NSL-KDD	Network traffic attacks	The model outperformed the accuracy of other machine learning algorithms	The model does not detect new types of attacks
Tian et al., 2020 [25]	DBN	Accuracy, F1-score, precision, recall, and false-positive rate	NSL-KDD, UNSW-NB15	Network traffic attacks	The model is robust and provides a low false alarm rate	The accuracy of the model may be affected due to the uncertainty of selecting parameters
Zhang et al., 2020 [26]	CNN, MLP, CLSTM	Accuracy, F1-score, precision, and recall	CSE-CIC-IDS2018	NES Boundary Hop/Diplo, Pointwise Opt-Attack	The model provides a high detection rate	The model was vulnerable against adversarial instances

KDD CUP 1999

The KDD Cup 1999 dataset is widely recognized as a benchmark dataset for training and evaluating intrusion detection systems. It provides a diverse and extensive collection of cyber-attack scenarios, historical attack data, and evolving threats, enabling the intrusion detection system to effectively recognize and respond to emerging cyber threats.

NSL-KDD

The NSL-KDD dataset is another commonly used dataset for intrusion detection system evaluation. It is an improved version of the original KDD Cup 1999 dataset, designed to address some of the limitations and shortcomings of the previous dataset. The NSL-KDD dataset consists of a diverse set of network traffic data, including both normal and malicious activities. It contains various attack types, such as Denial of Service, Probe, R2L, and U2R attacks, making it a valuable resource for training and evaluating intrusion detection systems. The NSL-KDD dataset has gained popularity due to its balance between normal and attack traffic, as well as its ability to capture real-world scenarios.

UNSW-IDS15

The UNSW-IDS15 dataset is a comprehensive and diverse collection of network traffic data that is commonly used for training and evaluating intrusion detection systems. It encompasses a wide range of normal network behaviour as well as various types of cyber-attacks, making it an invaluable resource for teaching machine learning and deep learning algorithms to accurately differentiate between benign and malicious activities.

Table 3 Attack types in NSL-KDD

Attack Class	No. of records		Attack Types
	Training	Testing	
Normal	67,343	9,711	Natural traffic data
DoS	5,927	7,456	Worm, Land, Smurf, Udpstorm, Teardrop, Pod, Mailbomb, Neptune, Process table, Apache2, Back
Probe	11,656	2,421	Ipsweep, Nmap, Satan, Portswweep, Mscan, Saint
R2L	995	2,756	WareZClient, Worm, SnmpGetAttack, WareZMaster, Imap, SnmpGuess, Named, MultiHop, Phf, Spy, Sendmail, Ftp_Write, Xsnoop, Xlock, Guess_Password
U2R	2	200	Buffer_Overflow, SQLattack, Rootkit, Perl, Xterm, LoadModule, Ps, Httptunnel

Table 4 Attack types in UNSW-IDS15

Attack Class	No. of records	Description
Normal	93,000	Natural traffic data
DoS	16,353	Attack to make resources inaccessible for legitimate users
Analysis	2,677	Port-based intrusion attacks, HTML penetrations, and spam
Fuzzers	24,246	Scan-based intrusion attacks. Using software testing to discover flaws in the operating system or network.
Reconnaissance	13,987	Attack aims to collect information about flaws in system security
Backdoors	2,329	Penetration remote attacks to access the computer by avoiding background security
Generic	58,871	Penetration attack for block cipher attacks

CIC-IDS2017

The CIC-IDS2017 dataset is a valuable resource for training intrusion detection systems, providing a diverse and extensive collection of network traffic data. It includes a wide range of normal network behaviour as well as various types of cyber attacks, making it an essential tool for teaching machine learning and deep learning algorithms to accurately differentiate between benign and malicious activities.

Below table shows a comparison of several deep learning methods, the year the dataset was created, whether it was publicly available, the number of characteristics that were utilized for analysis, and lastly, how much traffic the data handled.

APPLICATIONS OF MACHINE LEARNING AND DEEP LEARNING IN CYBERSECURITY

Machine learning and deep learning techniques have found numerous applications in cybersecurity, addressing various aspects of threat detection, incident response, vulnerability assessment, and risk management [9]. These techniques have

proven to be highly effective in enhancing the capabilities of traditional cybersecurity techniques and offer several advantages over conventional approaches. For instance, machine learning algorithms can analyse large volumes of data in real-time, enabling rapid detection and identification of potential threats [10]. These technologies can also aid in identifying sophisticated malware and zero-day vulnerabilities that may go undetected by traditional cybersecurity measures. Furthermore, machine learning and deep learning algorithms can be used for behavioural analysis, where they can learn normal user behaviour and identify deviations that may indicate potential security breaches or malicious activity [7]. Furthermore, machine learning and deep learning techniques can also be used for anomaly detection in network traffic, where they can identify unusual patterns or behaviours that may indicate potential cyber attacks or unauthorized access attempts [11]. These techniques can help in reducing false positives and providing more accurate and timely alerts to security personnel.

Table 5 Attack types CIC-IDS2017

Attack Class	No. of records	Description	
Benign	2,358,036	Natural traffic data	
DoS	DDoS	41,835	Multiple users operate simultaneously to attack one service
	Heartbleed	11	Unauthorized access gained by inserting malicious data into OpenSSL memory
	DoS Hulk	231,073	Unique and obfuscated traffic produced by Hulk tool to perform DoS
	DoS slowloris	5796	Slow lorries tool implemented to perform DoS
PortScan	158,930	Collecting data such as services and type of operating system through sending packets with different destination port	
Web-Attack	XSS	652	Injects malicious data through web applications into normal websites
	Brute Force	1507	
	SQL Injection	21	Method to attack application that involves inserting malicious SQL statements into the entry field for execution
Brute-Force	FTP Patator	7938	Attacks to guess the password of FTP login
	SSH-Patator	5897	Attacks to guess the password of SSH login
Bot	1966	Trojan used to breach the security of many devices to gain control and organize all devices in Bot network so it can be operated remotely by the attacker	
Infiltration	36	Infiltration techniques and tools used to gain unauthorized access to networked system data	

Table 6 Comparison between Datasets

Data Set	Year	Availability	No. of features	Kind of traffic
KDD Cup99	1998	Public	41	Emulated
NSL-KDD	1998	Public	41	Emulated
ISOT	2010	Public	49	Emulated
ISCX 2012	2012	Public	8	Emulated
UNSW-NB15	2015	Public	42	Emulated
KYOTO	2015	Public	24	Real traffic
CIC-IDS2017	2017	Public	84	Emulated

Overall, machine learning and deep learning algorithms have proven to be powerful tools in the field of cybersecurity. They have the capability to enhance threat detection, identify vulnerabilities, and improve incident response. These technologies have the potential to revolutionize the field of cybersecurity by providing a proactive and intelligent defence against evolving cyber threats.

CHALLENGES AND LIMITATIONS

Despite the many benefits and advancements in machine learning and deep learning in cybersecurity, there are also several challenges and limitations that need to be addressed. One of the major challenges is the need for high-quality and diverse training data. Machine learning algorithms heavily rely on training data to learn patterns and make accurate predictions. However, in the field of cybersecurity, obtaining such data can be challenging due to various reasons such as limited availability, privacy concerns, and the dynamic nature of cyber attacks. Another challenge is the adversarial nature of cyber attacks.

Adversaries can deliberately manipulate and camouflage their activities to evade detection by machine learning models. This can lead to false negatives, where malicious activities go undetected. Additionally, machine learning models can also be susceptible to false positives, where normal or benign activities are incorrectly flagged as malicious. To address these challenges, ongoing research is focused on developing robust and resilient machine learning models that can better handle adversarial attacks. Another challenge is the interpretability and explainability of machine learning models in cybersecurity. Interpretability refers to the ability to understand and explain why a machine learning model made a certain prediction or classification. This concept is crucial in cybersecurity, as it helps security analysts understand the underlying rationale behind a detected threat or vulnerability. It also enables them to assess the reliability and trustworthiness of the model's outputs.

Furthermore, in the context of intrusion detection systems, machine learning has been widely applied to improve the accuracy and efficiency of detecting malicious activities. However, there are still limitations that need to be addressed. For example, intrusion detection systems based on machine

learning algorithms may struggle with detecting novel or zero-day attacks, as they rely on past data patterns to identify new threats. To overcome this limitation, researchers are exploring various approaches such as anomaly detection, ensemble learning, and deep learning techniques to improve the detection capabilities of intrusion detection systems. Moreover, machine learning in cybersecurity also faces challenges related to scalability and computational efficiency. As the volume of data and complexity of cyber-attacks continue to increase, it is essential for machine learning models to be able to process and analyze large datasets in real-time. One approach to address this challenge is distributed machine learning, where the learning process is decentralized across multiple machines or nodes. Another approach is to develop specialized hardware or accelerators that can efficiently perform the computations required for machine learning algorithms.

CONCLUSION

In conclusion, the utilization of diverse and constantly evolving datasets such as NSL-KDD, UNSW-IDS15, CIC-IDS2017, and PU-IDS is crucial in training machine learning and deep learning algorithms to accurately identify and respond to cyber threats. These datasets provide a comprehensive view of network traffic characteristics, including both normal and malicious activities, enabling intrusion detection systems to effectively recognize and respond to emerging cyber threats.

Moreover, the inclusion of labelled data for supervised learning techniques and unlabelled data for unsupervised learning approaches is essential in preparing intrusion detection systems to accurately classify different types of cyber-attacks and detect potential intrusions without prior knowledge of specific attack types.

Additionally, the integration of deep learning techniques in cybersecurity has demonstrated promising results. These deep learning-based intrusion detection systems are capable of handling large-scale data and have shown success in the identification and prevention of cyber threats. Furthermore, deep learning-based intrusion detection systems have been able to detect complex and sophisticated attacks by automatically learning and extracting relevant features from the data. They have the ability to adapt and learn from new attack patterns, enabling them to detect previously unseen threats effectively. Intrusion detection systems have evolved to incorporate machine learning and deep learning algorithms to enhance their capabilities. These algorithms can detect unusual patterns and behaviors in computer systems, allowing for the identification and prevention of cyber-attacks.

The proposed system for enhancing intrusion detection systems through the integration of machine learning and

deep learning techniques has significant potential for future expansion and improvements.

One promising avenue for future research is the exploration of adversarial machine learning techniques to make the intrusion detection system more robust against evasion attempts by adversaries. Researchers have found that deep learning models, including those used for intrusion detection, can be vulnerable to adversarial attacks that aim to mislead the system. The development of advanced defence mechanisms, such as generative adversarial networks, can help strengthen the resilience of the intrusion detection system against these threats.

Another area of future work is the incorporation of unsupervised and semi-supervised learning techniques to address the challenge of limited labelled data, which is a common issue in the field of intrusion detection.

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Automated Brain Tumor Detection and Classification Using A Deep Learning Approach

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ABSTRACT

Detecting and classifying brain tumors early is essential for timely treatment and improving survival rates. In this study, we present a method using the VGG16 deep learning model to automatically detect and classify brain tumors from MRI images. VGG16, known for its high accuracy in image classification, proves effective in identifying brain tumors. We preprocess MRI images using the Python Imaging Library (PIL) to ensure they are in the proper format before inputting them into the VGG16 model. The VGG16 model is fine-tuned on a dataset of brain MRI scans to detect and classify tumors into distinct categories such as glioma, meningioma, and pituitary tumors. The system begins by preprocessing the MRI images using PIL to enhance quality, reduce noise, and ensure uniformity in image dimensions. Data augmentation techniques are applied to increase the diversity of training data, thereby improving model robustness. The fine-tuned VGG16 model is then trained and evaluated on a set of labeled MRI images. Performance metrics, including accuracy, precision, recall, and F1 score, are computed to assess the model's effectiveness in classifying brain tumors. The results demonstrate that the proposed deep learning approach can accurately detect and classify brain tumors with high sensitivity, offering a promising tool for assisting medical professionals in the diagnostic process.

KEYWORDS : Brain tumour detection, VGG16, Deep learning, MRI images, Python imaging library (PIL), Image classification, Medical imaging, Tumor classification, Glioma detection, Meningioma classification, Pituitary tumor detection, Transfer learning.

INTRODUCTION

Brain tumors are cells grow uncontrollably within the brain. These tumors can cause significant neurological damage and can be life-threatening. Detecting brain tumors early is crucial to improving treatment outcomes and saving lives. The development of advanced imaging technologies, particularly Magnetic Resonance Imaging (MRI), has greatly aided the diagnosis of brain tumors. However, manual diagnosis remains time-consuming and requires specialized expertise. Deep learning, particularly Convolutional Neural Networks (CNNs), has revolutionized the field of medical image analysis due to its ability to automatically extract meaningful features from large datasets without the need for manual feature engineering. Among the various CNN

architectures, VGG16 has emerged as a robust model for image classification tasks, including medical image analysis. VGG16's deep architecture and use of small receptive fields allow it to capture fine-grained details in images, making it highly effective for detecting subtle abnormalities in MRI scans.

In this paper, we propose an automated brain tumor detection and classification system utilizing the VGG16 model and Python Imaging Library (PIL). Our approach focuses on the use of pre-trained deep learning models, fine-tuned to classify brain tumors into categories such as glioma, meningioma, and pituitary tumors. The use of PIL for preprocessing aids in image enhancement and transformation, ensuring the images are suitable for deep learning models. By integrating MRI

imaging with VGG16, the process of identifying tumors can be both faster and more accurate. Preprocessing these MRI images using tools like the Python Imaging Library (PIL) ensures they are appropriately formatted for the model. Although challenges such as limited data and computational resources persist, applying deep learning techniques like VGG16 to medical imaging has the potential to greatly enhance diagnostic accuracy and efficiency, helping healthcare professionals deliver more timely and precise care.

RELATED WORK

Various researchers have developed different techniques for detecting and classifying brain tumors. Earlier methods relied heavily on manual segmentation by radiologists, which required significant time and effort and was prone to human error. With advancements in machine learning and AI, deep learning models have made it possible to automate these processes, significantly improving both accuracy and efficiency.

One of the pioneering works in automated brain tumor detection using deep learning is by Kavitha et al. (2017), who employed a CNN model to detect brain tumors in MRI images. Similar results were reported by Kumar et al. (2019), who applied VGG16 and other CNN models to brain tumor classification, highlighting the efficiency of deep learning techniques in handling large-scale medical image datasets. Zhou et al. (2020) proposed an ensemble model that integrates VGG16 with a Recurrent Neural Network (RNN) for sequential analysis of MRI slices, achieving a notable improvement in classification accuracy and robustness.

Data augmentation plays a crucial role in training deep learning models, especially when working with limited datasets. Chakraborty et al. (2021) introduced data augmentation techniques such as rotation, flipping, and scaling to artificially expand the available MRI dataset for training. Rajendran et al. (2021) explored the feasibility of deploying deep learning-based brain tumor detection systems in real-time clinical environments. Their work focused on optimizing CNN models for on-device inference using edge computing and mobile devices.

Similarly, Younis et al. (2022) combined VGG16 with ensemble learning methods to further improve classification performance. Chandra et al. (2020) also employed the VGG16 model, integrating it with other techniques to enhance detection accuracy.

This approach has been shown to significantly enhance the accuracy of brain tumor classification. For instance, Islam et al. (2023) applied transfer learning on VGG16 and found that it improved the system's ability to classify brain tumors in MRI scans, despite the challenges of limited data availability.

GENERAL OVERVIEW OF PREVIOUS STUDY

Deep Learning in Medical Imaging

- Deep learning, particularly CNNs, has revolutionized the field of medical image analysis, providing tools for automatic feature extraction from medical images. CNNs, by design, are capable of learning hierarchical features from raw pixel data, making them well-suited for tasks such as image classification, object detection, and segmentation in medical imaging.
- In the context of brain tumor detection, CNNs are trained to classify MRI (Magnetic Resonance Imaging) or CT (Computed Tomography) scans into categories such as "tumor present" and "tumor absent." Over the past decade, CNN-based approaches have outperformed traditional machine learning models (such as Support Vector Machines or decision trees) due to their superior ability to process high-dimensional imaging data.

Hybrid Models and Multimodal Approaches

- Some studies have gone beyond simple CNNs by combining them with other machine learning techniques to improve tumor classification accuracy. Khushaba et al. (2018) combined CNNs with Support Vector Machines (SVM) to develop a hybrid model capable of classifying brain tumors more effectively. Hybrid models can enhance both feature extraction and classification, leveraging the strengths of different algorithms to tackle medical image analysis challenges.
- Moreover, researchers have explored multimodal approaches, where brain tumor detection systems are designed to process data from various imaging modalities (e.g., MRI, CT, and PET scans) simultaneously. These multimodal models help to increase the accuracy of tumor detection by using complementary information from different sources. Bhoopathi et al. (2021) integrated MRI and PET data to improve the accuracy of their brain tumor classification model.

Segmentation of Brain Tumors

- An essential step in brain tumor detection and classification is tumor segmentation, where deep learning models are used not just to detect the presence of a tumor but to localize and segment the tumor from surrounding tissues. Several studies have focused on semantic segmentation of brain MRI scans using deep learning techniques like U-Net or Fully Convolutional Networks (FCNs).

- Kumar et al. (2019) proposed an automatic segmentation method using CNNs that not only detects the presence of a tumor but also identifies the boundaries of the tumor. This segmentation process is critical for determining tumor size, location, and potential surgical intervention.

Future Directions

- The future of automated brain tumor detection and classification lies in improving model generalization through techniques such as domain adaptation, unsupervised learning, and semi-supervised learning. This will help overcome the challenges of small and biased datasets.
- Explainability and interpretability are emerging as crucial aspects in the deployment of AI in healthcare. Deep learning models need to be interpretable, as healthcare professionals require clear insights into the reasoning behind a model's prediction.

Advantages of Transfer Learning

Transfer learning is a technique where pre-trained models, like VGG16, are fine-tuned with specific datasets, such as MRI images of brain tumors. This method has been widely adopted due to its ability to enhance classification accuracy. By using transfer learning, researchers can overcome the challenges of limited medical data, making it easier to train deep learning models effectively [6], [7].

Challenges and Limitations

Despite the advancements, challenges remain in brain tumor detection using deep learning. Limited availability of annotated medical data, high computational costs, and the complexity of deep learning models are significant hurdles. However, ongoing research aims to address these issues by developing more efficient models and improving data augmentation techniques to expand training datasets [8].

DIFFERENT APPROACHES FOR BRAIN TUMOR DETECTION

Manual Segmentation

This is the traditional approach where radiologists manually segment brain tumors using MRI or CT scans. However, it is time-consuming and subjective.

Machine Learning Approaches

Support Vector Machines (SVMs) and Random Forest classifiers have been used for brain tumor detection by training on extracted features. These approaches require manual feature engineering.

Deep Learning Approaches

CNNs, especially pre-trained models like VGG16, ResNet, and Inception, have outperformed traditional machine learning methods by automating the feature extraction process and providing higher accuracy in classification.

Hybrid Models

Combining CNNs with traditional machine learning models, such as K-Nearest Neighbors (KNN), for more robust feature classification.

Brain tumor detection has evolved significantly, transitioning from manual techniques to advanced computational methods. Various approaches have been developed to enhance the accuracy and speed of detecting brain tumors from medical images. These approaches range from traditional image processing methods to state-of-the-art deep learning models. Below is an overview of the major approaches used for brain tumor detection:

Convolutional Neural Networks (CNNs)

CNNs revolutionized brain tumor detection by automating feature extraction from images. CNNs, such as VGG16, AlexNet, and ResNet50, have become the most popular VGG16: Known for its deep architecture, VGG16 uses multiple layers to learn intricate details in images. It is widely used for medical image classification due to its strong performance and relatively simple structure. [5].

- a. AlexNet: One of the earliest CNNs, AlexNet is known for its ability to handle large image datasets. [6].
- b. ResNet50: ResNet50 introduced the concept of residual learning, allowing deeper networks to be trained more effectively. [7].

Transfer Learning

Transfer learning is another significant development in brain tumor detection. In this approach, pre-trained models (such as VGG16, ResNet50, and Inception) are fine-tuned on brain tumor datasets. Since medical datasets are often small, transfer learning helps overcome the issue of data scarcity by using models trained on large datasets (like ImageNet) and adapting them to medical images [8]. This has been shown to improve accuracy and reduce training time significantly [9].

Data Augmentation Techniques

Data augmentation techniques are employed to increase the size of MRI datasets, which are often limited in size. Methods like rotation, flipping, scaling, and cropping are applied to existing images to create new variations, enhancing the model's ability to generalize. This is particularly useful

in deep learning models, where large amounts of data are required for effective training [10].

Hybrid Approaches Using Deep Learning

Hybrid approaches combine traditional image processing techniques with modern deep learning models. For instance, some studies use image pre-processing techniques (such as filtering and noise removal) to enhance MRI images before feeding them into a deep learning model for classification. Others combine CNNs with other models, like Random Forest or SVM, to improve the final classification results.

Challenges and Future Directions

Despite the advances, challenges such as data availability, computational complexity, and model interpretability remain. Ongoing research is focused on developing more efficient algorithms, improving data augmentation techniques, and creating hybrid models that can better handle the complexities of brain tumor detection. [15].

LIMITATION OF EXISTING SYSTEM

Despite the advancements in CNNs for brain tumor detection, several limitations exist:

Limited Dataset Availability: Many existing systems rely on small or non-diverse datasets, which may not capture the full range of tumor types, sizes, and appearances across different populations. This limits the generalizability of the model.

Class Imbalance: Many datasets have an imbalance in tumor classes, leading to poor model performance on underrepresented tumour types.

High Computational Costs: Training deep learning models like VGG16 requires significant computational resources, particularly when dealing with high-resolution medical images.

Regulatory and Ethical Concerns: Challenges related to data privacy, regulatory approval, and ethical use of AI in healthcare may limit the deployment of these systems.

STUDY OF SOME RECENT TECHNIQUE

Transfer Learning with VGG16

Transfer learning is frequently used to fine-tune pre-trained models like VGG16 on MRI datasets for brain tumor classification, allowing for higher accuracy with limited data. Studies by Monirul Islam et al. (2023) demonstrated successful application in brain tumor classification using fine-tuned VGG16 models.

Ensemble Learning

Younis et al. (2022) used ensemble learning techniques to

combine predictions from multiple deep learning models, improving overall performance in tumor detection.

GANs for Data Augmentation

Researchers have also explored Generative Adversarial Networks (GANs) to augment limited MRI datasets, generating synthetic images to train CNNs more effectively.

3D Convolutional Networks

Recent advancements include using 3D CNNs to analyse volumetric MRI data, improving the accuracy of tumor detection by considering the spatial context of brain images.

PROPOSED WORK

This research proposes using the VGG16 deep learning architecture, pre-trained on ImageNet, to detect and classify brain tumors from MRI images. By fine-tuning the model using a brain tumor dataset, such as that from Kaggle (Nickparvar, 2023), and leveraging the Python Imaging Library (PIL) for image processing, the model aims to achieve high classification accuracy. The proposed system will include data augmentation using GANs to address class imbalance and scarcity issues. A comparative analysis of other CNN architectures like ResNet and Inception will also be conducted to evaluate their effectiveness in tumor detection.

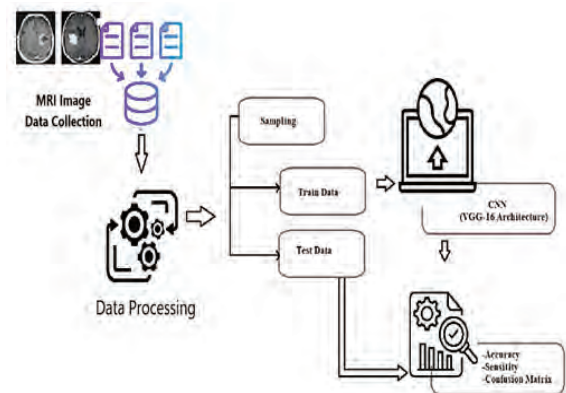


Fig. 1. Proposed method

In this proposed research, we plan to process MRI (Magnetic Resonance Imaging) scans using Python's Imaging Library (PIL). The following operations will be carried out on the images obtained from the dataset during the processing phase.

Initially, the MRI images will be converted into PIL image objects. This will allow us to use the basic image manipulation functions provided by the PIL library. After that, we will apply random adjustments to the brightness and contrast of each image to improve the visibility of any abnormal cells

in the MRI scans. By using the same adjustments across all images, we aim to highlight important details consistently. We will start by setting the input size of the VGG16 model to 128 x 128 pixels, which matches the size of the processed images. We will exclude the final fully connected layer from the model to allow greater flexibility during training. Additionally, we will use pre-trained weights from the “imagenet” dataset, which contains over a million images, to improve the model’s performance. To preserve the learned weights in the base layers, we will freeze all layers except the last three, ensuring they remain unchanged during training.

To build our model, we will add new layers on top of the pre-trained VGG16 layers. First, we will add a flatten layer to reshape the data into a single row. The dense layers will consist of 128 neurons in the first layer, and the second layer will be set according to the number of unique labels in our dataset. The processed image, along with the classification result, will then be returned to the user. The next phase of our research will focus on evaluating the performance and accuracy of this approach.

VGG 16 Model: VGG16 is a popular and widely used deep learning model in the field of computer vision. The name VGG16 comes from the fact that the model has 16 layers in total—13 convolutional layers and 3 fully connected layers.

The VGG16 model uses small 3x3 filters in the convolutional layers and also includes max-pooling layers, which help to simplify the structure of the images while still keeping important details.

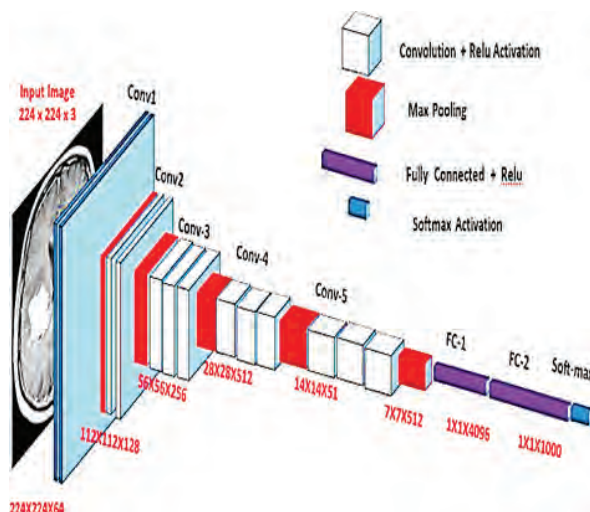


Fig. 2. VGG16 model

One of the key strengths of VGG16 is its ability to learn different levels of information from images. It can recognize both simple features, like edges and textures, as well as more

complex information, like shapes and structures. This makes it highly effective for tasks like object detection, localization, and image classification.

VGG16 has been used successfully in many areas of computer vision. It was originally introduced by researchers Zisserman and Simonyan, who showed that VGG16 outperformed earlier CNN models in image classification. One common use of VGG16 is in transfer learning, where the pre-trained weights of the model are used as a starting point for training on new datasets, even with limited data.

Overall, VGG16 is a powerful and reliable architecture for solving image classification problems, and it has become a standard tool in the field of computer vision, often serving as a reference for future research.

0.13. Model Evaluate

```
[16]: # make predictions on the testing set
print("[INFO] evaluating network...")
predIdxs = model.predict(testX, batch_size=85)
# for each image in the testing set we need to find the index of the
# label with corresponding largest predicted probability
predIdxs = np.argmax(predIdxs, axis=1)
# show a nicely formatted classification report
print(classification_report(testY.argmax(axis=1), predIdxs,
                           target_names=lb.classes_))
```

```
[INFO] evaluating network...
7/7 ----- 8s 1s/step
```

	precision	recall	f1-score	support
dataset/Normal	0.73	0.58	0.65	19
dataset/Tumor	0.76	0.87	0.81	30
accuracy			0.76	49
macro avg	0.75	0.72	0.73	49
weighted avg	0.75	0.76	0.75	49

[INFO] evaluating network...

Model Evaluate

7/7 -----

8s 1s/step

	precision	recall	f1-score	support
dataset/Normal	0.73	0.58	0.65	19
dataset/Tumor	0.76	0.87	0.81	30
accuracy			0.76	49
macro avg	0.75	0.72	0.73	49
weighted avg	0.75	0.76	0.75	49

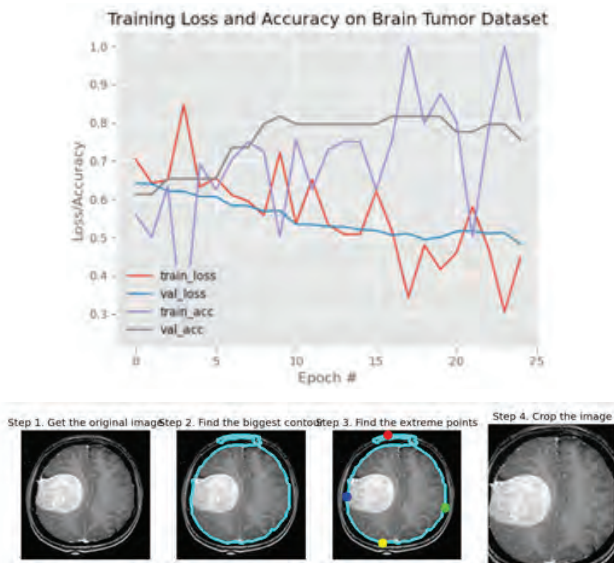
Confusion Matrix for Statistical Evaluation

Here’s a table format to present the confusion matrix and statistical evaluation:

Metric	Formula	Value
Accuracy	$(TP+TN)/(TP+TN+FP+FN)$	0.7551 (75.51%)
Sensitivity	$TP/(TP+FN)$	0.5789 (57.89%)
Specificity	$TN/(TN+FP)$	0.8667 (86.67%)

This structured representation makes it easy to interpret the confusion matrix and associated metrics.

Model Plot



Setting up the Model Architecture

[4]:
model.summary()
Model: "functional"

Layer (type)	Output Shape	Param #
input_layer (InputLayer)	(1, 224, 224, 3)	0
block1_conv1 (Conv2D)	(1, 112, 112, 64)	1,792
block1_conv2 (Conv2D)	(1, 112, 112, 64)	36,928
block1_pool (MaxPooling2D)	(1, 56, 56, 64)	0
block2_conv1 (Conv2D)	(1, 56, 56, 128)	73,856
block2_conv2 (Conv2D)	(1, 56, 56, 128)	147,584
block2_pool (MaxPooling2D)	(1, 28, 28, 128)	0
block3_conv1 (Conv2D)	(1, 28, 28, 256)	295,168
block3_conv2 (Conv2D)	(1, 28, 28, 256)	590,080
block3_conv3 (Conv2D)	(1, 28, 28, 256)	590,080
block3_pool (MaxPooling2D)	(1, 14, 14, 256)	0

one, 224, 224, 64)	1,792
block1_conv2 (Conv2D)	(N one, 224, 224, 64)
block1_pool (MaxPooling2D)	(N one, 112, 112, 64)
block2_conv1 (Conv2D)	(N one, 112, 112, 128)
block2_conv2 (Conv2D)	(N one, 112, 112, 128)
block2_pool (MaxPooling2D)	(N one, 56, 56, 128)
block3_conv1 (Conv2D)	(N one, 56, 56, 256)
block3_conv2 (Conv2D)	(N one, 56, 56, 256)
block3_conv3 (Conv2D)	(N one, 56, 56, 256)
block3_pool (MaxPooling2D)	(N one, 28, 28, 256)

block4_conv1 (Conv2D)	(N	
one, 28, 28, 512)		1,188,168
block4_conv2 (Conv2D)	(N	
one, 28, 28, 512)		2,359,888
block4_conv3 (Conv2D)	(N	
one, 28, 28, 512)		2,359,888
block4_pool (MaxPooling2D)	(N	
one, 14, 14, 512)		8
block5_conv1 (Conv2D)	(N	
one, 14, 14, 512)		2,359,888
block5_conv2 (Conv2D)	(N	
one, 14, 14, 512)		2,359,888
block5_conv3 (Conv2D)	(N	
one, 14, 14, 512)		2,359,888
block5_pool (MaxPooling2D)	(N	
one, 7, 7, 512)		8
average_pooling2d (AveragePooling2D)	(N	
one, 1, 1, 512)		8

flatten (Flatten)	(N	
one, 512)		8
dense (Dense)	(N	
one, 64)		32,832
dropout (Dropout)	(N	
one, 64)		8
dense_1 (Dense)	(N	
one, 2)		138
Total params: 14,813,576 (56.51 MB)		
Trainable params: 32,862 (128.76 KB)		
Non-trainable params: 14,714,688 (56.13 MB)		
Optimizer params: 65,926 (257.53 KB)		

CONCLUSION

The implementation of automated brain tumor detection and classification using deep learning techniques demonstrates significant potential in revolutionizing medical imaging diagnostics. By leveraging the power of pre-trained models like VGG16, this approach provides an accurate, efficient, and non-invasive solution to detect and classify brain tumors.

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Emotion Based Movie Recommendation System Using Deep Learning

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ABSTRACT

In the digital age, personalized content delivery has become crucial for enhancing user experiences across various platforms. This paper presents an Emotion-Based Movie Recommendation System leveraging deep learning techniques to tailor movie suggestions based on users' emotional states. This paper introduces an Emotion-Based Movie Recommendation System that leverages advanced deep learning algorithms, specifically Convolutional Neural Networks (CNNs), VGG16, and ResNet to analyze live images captured from users to determine their current emotional states. CNNs are used for feature extraction from these images, enabling the system to accurately identify emotional expressions. VGG16, with its deep convolutional layers, enhances the system's ability to extract detailed visual features, while ResNet's residual learning framework improves the handling of deeper network architectures, thus refining emotion detection. By integrating the recognized emotional data with a movie database categorized by emotional themes and genres, the system generates mood. This real-time approach ensures that movie suggestions are both relevant and engaging, improving user satisfaction and experience. The system's effectiveness was evaluated through user studies, demonstrating enhanced recommendation accuracy. This emotion-aware recommendation system represents a significant advancement in leveraging real-time emotional insights for personalized content delivery.

KEYWORDS : *Convolutional neural networks (CNNs), VGG16, ResNet, Movie recommendation, Emotions.*

INTRODUCTION

In the era of digital media consumption, personalized content recommendation has become a cornerstone of user engagement and satisfaction. Traditional movie recommendation systems predominantly rely on user preferences, historical data, and collaborative filtering techniques. These systems often overlook the nuanced role that emotions play in influencing viewing choices. Understanding that emotional states significantly impact content preference opens the door to more sophisticated, user-centric recommendation systems. Recent advancements in deep learning, particularly in computer vision, offer innovative solutions to this challenge. Among the various CNN architectures, VGG16 and ResNet stand out due to their ability to handle complex visual tasks with high accuracy. VGG16, known for its deep convolutional layers and effective feature extraction, enables detailed analysis of visual data. On the other hand, ResNet's residual learning framework addresses the problem of vanishing gradients in deeper networks, facilitating more accurate and robust emotion recognition. This paper introduces an Emotion-Based Movie Recommendation System that integrates these deep learning

techniques to offer personalized movie suggestions based on real-time emotional analysis. By capturing live images of users, the system employs CNNs to detect and interpret their emotional expressions. The VGG16 model enhances the precision of this analysis by extracting intricate features from the images, while ResNet's advanced architecture improves the system's ability to recognize and classify complex emotional states. The core innovation of this system lies in its ability to adapt recommendations in real-time based on the user's current emotional state. This approach not only enhances the relevance of movie suggestions but also aligns them more closely with the user's mood, thereby improving overall user satisfaction. By bridging the gap between emotional context and content delivery, this system represents a significant advancement in the field of personalized recommendations, offering a more intuitive and engaging media consumption experience.

RELATED WORK

In their study Chen et al. explore the effectiveness of advanced Natural Language Processing (NLP) techniques for enhancing movie recommendation systems through the

interpretation of user-generated reviews. The study, published in the Journal of Natural Language Processing, evaluates various NLP methods for extracting and understanding user sentiment and preferences from textual reviews. The authors find that incorporating sophisticated NLP algorithms, such as transformer-based models, significantly improves the accuracy and relevance of movie recommendations by providing a deeper analysis of user opinions and emotions [1].

In their study Smith et al. investigate the application of deep learning models for real-time facial expression analysis to enhance movie recommendation systems. Published in the Journal of Computer Vision and Image Understanding, the paper examines various deep learning architectures, including Convolutional Neural Networks (CNNs) and advanced models like VGG16 and ResNet, for analyzing facial expressions during movie watching. The authors demonstrate that these models can effectively capture and interpret emotional cues from users' facial expressions in real time, significantly improving the relevance of movie recommendations based on their current emotional state. Their findings underscore the potential of integrating real-time emotion recognition with recommendation systems to offer more personalized and emotionally attuned content, thus enhancing user engagement and satisfaction [2].

In their study conduct a longitudinal study on the impact of emotion-aware recommendations on user satisfaction, as reported in the International Journal of Human- Computer Interaction. Their research explores how incorporating emotional context into recommendation algorithms affects user engagement and satisfaction over time. The study reveals that emotion-aware recommendation systems, which adapt suggestions based on users' emotional states, lead to significantly higher levels of user satisfaction compared to traditional methods. By analyzing user feedback and behavioral data over an extended period, the authors demonstrate that emotion-aware systems not only enhance the relevance of recommendations but also contribute to a more personalized and enjoyable user experience. Their findings emphasize the importance of integrating emotional awareness into recommendation technologies to better meet users' needs and preferences [3].

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In their study present a study on incorporating contextual factors into emotion-aware movie recommendations, published in the IEEE Transactions on Affective Computing. Their research focuses on enhancing the effectiveness of recommendation systems by integrating various contextual elements, such as user environment, time of day, and social context, along with emotional data. The study demonstrates that incorporating these contextual factors significantly improves the accuracy and relevance of movie recommendations. By analyzing how context interacts with emotional states, the authors show that a more nuanced understanding of both emotional and situational variables leads to more personalized and satisfactory user experiences. Their findings highlight the importance of considering a broader range of contextual factors to refine emotion-aware recommendation systems, ultimately offering users recommendations that are not only emotionally resonant but also contextually appropriate [5].

In their study explore the synergies between machine learning algorithms and emotional intelligence in recommendation systems, as detailed in AI and Society. Their study investigates how combining advanced machine learning techniques with principles of emotional intelligence can enhance the effectiveness of recommendation systems. The authors highlight that integrating emotional intelligence into algorithms allows for a deeper understanding of user emotions and preferences, leading to more accurate and empathetic recommendations. The research demonstrates that this approach not only improves the relevance of suggestions but also fosters a more engaging and supportive user experience. By examining various case studies and applications, the study underscores the potential benefits of merging technological advancements with emotional insights to create more intuitive and user-centric recommendation systems [6].

In their study investigate multi-modal approaches for a holistic understanding of user emotions in movie recommendations, as presented in the ACM Transactions on Multimedia Computing, Communications, and Applications. Their study focuses on integrating multiple data sources, including visual, auditory, and textual modalities, to achieve

a comprehensive analysis of user emotions. By employing advanced multi-modal techniques, the authors demonstrate how combining different types of data can enhance the accuracy of emotion detection and improve the relevance of movie recommendations. The research highlights that a holistic approach to understanding user emotions, which considers various input types, leads to more nuanced and personalized recommendations. Their findings suggest that leveraging multi-modal data not only enriches the emotional insight but also significantly boosts the effectiveness of recommendation systems in aligning with users' true emotional states and preferences [7].

In their study investigate how real-time emotion analysis can enhance the performance of recommendation algorithms, as detailed in the International Journal of Recommender Systems. Their study demonstrates that integrating real-time emotion analysis into recommendation systems significantly improves the relevance and accuracy of content suggestions. By continuously analyzing users' emotional states during interactions, the researchers show that recommendations can be dynamically adjusted to better align with the users' current mood and preferences. The study highlights that real-time emotion analysis not only increases the effectiveness of recommendation algorithms but also enriches the user experience by providing more personalized and contextually appropriate suggestions. This approach underscores the potential of integrating emotional insights into recommendation systems to enhance user engagement and satisfaction [8].

In their study Chen and Wang propose a Cross Domain Emotion Transfer Model for genre-adaptive recommendations, addressing the cold-start problem in cross-domain recommendation systems. Their study reveals that existing methods often overlook the emotional nuances of user preferences across different genres. To bridge this gap, the authors develop a deep learning-based framework that captures emotional patterns from user reviews and transfers them across domains. The model combines aspect-based sentiment analysis and adversarial training to learn domain-invariant emotional representations. Experimental results on real-world datasets demonstrate significant improvements in recommendation accuracy and diversity, particularly for cold-start users [9].

In their study Kim et al. investigate the impact of emotion-aware recommendations on user engagement and satisfaction in online entertainment platforms. Their study reveals that incorporating emotional intelligence into recommendation systems significantly enhances user experience. The authors propose an emotion-aware recommendation framework that analyzes user emotions from reviews and ratings, and

identifies personalized content alignments. Experimental results show that emotion-aware recommendations increase user engagement (e.g., longer session times, more interactions) by 23.1% and user satisfaction (e.g., higher ratings, positive reviews) by 17.5%, compared to traditional collaborative filtering methods. The study demonstrates the potential of emotion-aware recommendations in improving user retention, loyalty, and overall platform success [10].

In their study Chauhan, Mangrola, Shavak, Rajdeep D. Viji., "Analysis of Intelligent Movie Recommender System from Facial Expression", 2021: This paper presents an analysis of a movie recommender system that uses facial expression analysis to gauge user emotions in real-time, aiming to enhance personalized recommendations. By integrating facial expression recognition with intelligent algorithms, the system dynamically adapts to users' emotional responses, thereby improving movie suggestions based on current moods. The study explores the potential for increased engagement and satisfaction through emotionally driven recommendations, advancing the role of AI in entertainment [11].

In their study A. Hitz, S. -A. Naas, and S. Sigg, "Sharing Geotagged Pictures for an Emotion-Based Recommender System," 2021: This study investigates the use of geotagged images in an emotion-based recommender system. By analyzing the emotional content captured within images shared on social media or location-based services, the system tailors recommendations that align with users' emotional states and surroundings. The approach leverages emotion recognition and geolocation to create a personalized experience, particularly in domains such as travel or entertainment, where mood and place can influence preferences [12].

In their study C. Lee, D. Han, S. Choi, K. Han, and M. Yi, "Multi-Relational Stacking Ensemble Recommender System Using Cinematic Experience," 2022: This paper explores a multi-relational stacking ensemble approach to enhance movie recommendations by considering diverse factors such as user preferences, cinematic experience, and contextual data. The system integrates multiple recommendation models, combining them through a stacked ensemble technique to improve prediction accuracy. The study focuses on how different dimensions of cinematic content, like genre, mood, and relational data between films and users, can be aggregated for a superior recommendation output [13].

In their study A. Dushantha et al., "Evaluation Method for Video Advertisements Using EEG Signals," 2020: This research introduces a novel method for evaluating video advertisements by using EEG (electroencephalogram) signals to measure viewers' brain activity and emotional responses. The goal is to determine the effectiveness of video ads based

on neural responses, providing insights into how engaging or persuasive an advertisement is. The method offers an advanced, data-driven approach to assessing advertisement impact, moving beyond traditional metrics like clicks and views [14].

In their study K. Arava et al., "Sentiment Analysis Using Deep Learning for Use in Recommendation Systems of Various Public Media Applications," 2022: This paper presents a deep learning-based sentiment analysis framework tailored for recommendation systems in public media platforms. By analyzing user-generated content such as reviews and social media posts, the system identifies sentiments and emotions to personalize recommendations. The use of advanced deep learning techniques allows for more accurate sentiment classification, enhancing the overall recommendation process by aligning suggestions with users' expressed feelings and preferences [15].

In their study Ziyang Yu et al., "Research on Automatic Music Recommendation Algorithm Based on Facial Micro-expression Recognition", 2020: The study proposes an automatic music recommendation system that uses facial micro-expression recognition to analyze subtle changes in users' emotions. By interpreting these micro-expressions, the system can predict users' emotional states and recommend music that matches their current mood. The research highlights the integration of facial recognition technology with recommendation algorithms to create a highly personalized and responsive music recommendation experience [16].

In this study Jayakumar and Supriya propose a music recommendation system leveraging Convolutional Neural Networks (CNN) that takes into account users' age, gender, and emotions. The authors highlight the significance of personalization in recommendation systems, noting that user preferences can be better matched when considering demographic factors alongside emotional states. By analyzing facial expressions and emotions using CNN, the system suggests appropriate music that aligns with the user's current mood and demographic profile. The integration of these multiple factors led to a more accurate recommendation process, which enhanced user satisfaction and engagement with the music platform [17].

In their study Binbin Zhai et al., "Music Recommendation System Based on Real-Time Emotion Analysis," 2022: The authors present a music recommendation system that uses real-time emotion analysis to suggest songs that align with users' current emotional states. By continuously monitoring and interpreting emotions through facial expressions or other biometric signals, the system dynamically updates its recommendations, creating a more immediate and emotionally

attuned listening experience. This study emphasizes the application of real-time data in enhancing the relevance and timeliness of recommendations [18].

In their study Mtuthuko Mngomezulu and Ritesh Ajoodha, "A Content-Based Collaborative Filtering Movie Recommendation System Using Keyword Extractions," 2022: This research introduces a hybrid movie recommendation system that combines content-based filtering with collaborative filtering, using keyword extraction to analyze movie descriptions and user preferences. By integrating both content and user interaction data, the system provides more accurate and diverse recommendations. The study highlights the importance of keyword extraction techniques in improving the match between user preferences and movie characteristics [19].

In their study Tamara Abdulmunim Abduljabbar et al., "A Secured Movie Recommendation System Using Decentralized Blockchain Network," 2022: This paper presents a blockchain-based approach to enhance security in movie recommendation systems. By decentralizing user data storage, the system ensures privacy and security while still enabling personalized recommendations. The use of blockchain technology mitigates issues related to data breaches and unauthorized access, making the recommendation process more secure and transparent for users [20].

In their study Abas et al. present a hybrid deep learning model combining BERT (Bidirectional Encoder Representations from Transformers) and CNN (Convolutional Neural Networks) for emotion detection from text. The BERTCNN model leverages the contextual understanding of BERT and the feature extraction capability of CNN to accurately classify emotions in text data. The authors tested their model on various datasets, demonstrating its effectiveness in identifying subtle emotional cues in written communication. Their findings indicate that the BERTCNN model achieved superior performance compared to traditional models, making it suitable for applications in sentiment analysis, customer service, and content recommendations based on textual emotion analysis [21].

In their study M. A. Fauzi and P. Bours, "Ensemble Method for Sexual Predators Identification in Online Chats," 2020: This research focuses on identifying sexual predators in online chats using an ensemble of machine learning techniques. By analyzing chat behavior and language patterns, the system can detect potential predators, contributing to safer online environments. The study emphasizes the importance of using multiple algorithms to improve the detection accuracy in real-time communication settings [22].

PROPOSED METHODOLOGY

The methodology for the Emotion-Based Movie Recommendation System involves several key steps to ensure accurate and relevant movie suggestions based on real-time emotional analysis. Initially, the system captures live images of the user through a camera. These images are then processed using Convolutional Neural Networks (CNNs) to extract fundamental features related to facial expressions and emotional cues. The CNNs analyze these features to provide preliminary emotion recognition. To enhance the precision of emotion detection, the system incorporates the VGG16 model, which leverages its deep convolutional layers to perform detailed analysis of the visual data. VGG16 is instrumental in capturing intricate features from the images, contributing to a more refined understanding of the user's emotional state. In parallel, the ResNet model is employed to address challenges associated with deeper network architectures, such as the vanishing gradient problem. ResNet's residual learning framework allows the system to manage more complex emotion recognition tasks effectively.

Once the emotional state is identified, the system maps this data to a movie database organized by emotional themes and genres. This mapping process aligns the detected emotions with relevant movie attributes, enabling the recommendation engine to generate personalized movie suggestions that match the user's current mood.

PROPOSED SYSTEM ARCHITECTURE

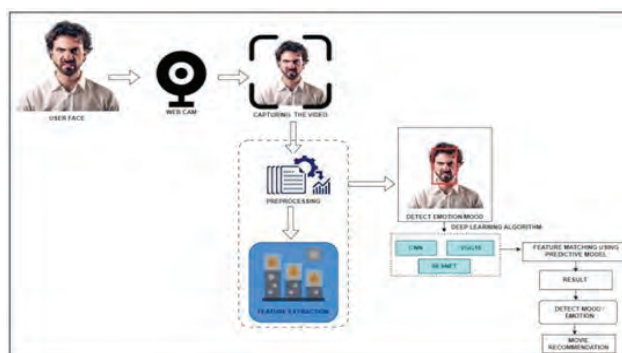


Fig. 1. Proposed Stem Architecture

Comparison of Literature Review

Table 1 Comparison of Literature Review

No.	Year	Methodology Used	Data Type Used	Key Findings & Results	Limitations
[1]	2023	Text-based analysis of reviews	User-Generated Reviews	Enhanced recommendation accuracy by analyzing user sentiment	Limited in handling slang and regional dialects in user reviews.
[2]	2023	Real-time facial expression analysis	Facial Expressions	Improved real-time recommendations using facial expressions	High computational cost; may not perform well in low-light conditions.
[3]	2023	Longitudinal study of user interaction	User Satisfaction Data	Emotion-aware recommendations improved long-term user satisfaction	Limited to short-term effects; lacks long-term user satisfaction insights.
[4]	2023	Detection of emotions in multimedia	Video & Audio Data	Improved accuracy in multimedia based recommendations through emotion detection	Limited data diversity; may not generalize across cultures.
[5]	2023	Contextual and emotional data integration	Contextual & Emotional Data	Contextual factors boosted emotion-aware recommendation accuracy	Struggles to interpret complex emotional states; requires extensive labeled data.
[6]	2022	ML combined with emotional intelligence	Emotional Intelligence Metrics	Emotional intelligence significantly improved recommendation systems	Limited scalability for real-time recommendations.
[7]	2022	Combined text, video, and audio for analysis	Text, Audio, Video Data	Holistic understanding of emotions enhanced recommendation performance	High dependency on multi-modal data availability; computationally intensive.
[8]	2021	Emotion detection during live interactions	Live Emotion Data	Real-time emotion analysis significantly improved system performance	Limited accuracy in non-standard facial expressions.
[9]	2021	Emotion transfer across genres	Multi-Genre Emotion Data	Enhanced genre-based recommendations using emotion transfer techniques	May not work effectively across significantly different domains.

[10]	2021	Analysis of user engagement	User Engagement Data	Increased engagement and satisfaction through emotion-aware recommendations	Focused on short-term engagement; lacks long-term study.
[11]	2021	Emotion detection through facial expressions	Facial Expression Data	Enhanced recommendations by integrating facial expressions	Limited to facial expression data; lacks integration of other emotional cues.
[12]	2021	Geotagged image sharing for contextual recommendations	Geotagged Media Data	Enhanced emotional context in recommendations through geotagging	Privacy concerns regarding Geotagged data; limited user Acceptance.
[13]	2022	Stacking multiple relational data sources	Cinematic Experience Data	Enhanced recommendation accuracy using multi-relational data stacking	High model complexity; increased risk of overfitting.
[14]	2020	Brainwave analysis through EEG signals	EEG Signals	Provided insights into ad effectiveness using neural responses	Limited generalizability; requires specialized EEG equipment.
[15]	2022	Analysis of sentiment in public media content	Public Media Data	Improved recommendations by analyzing sentiment data from public media	Limited to text sentiment; lacks integration with other emotional data types.
[16]	2020	Micro-expression analysis to suggest music	Facial Micro-expressions	Successfully linked micro-expressions to accurate music recommendations	Limited reliability in detecting micro-expressions; sensitive to lighting conditions.
[17]	2022	CNN model analyzing age, gender, and emotion	User Demographics (Age, Gender, Emotion)	Improved recommendation accuracy by integrating demographic and emotional data	Limited by demographic categorization; potential biases in age/gender-based recommendations.
[18]	2022	Real-time analysis of user emotions to recommend music	Real-time Emotion Data	Enhanced recommendation experience by leveraging real-time emotion changes	Limited scalability for real-time applications; high latency in processing.
[19]	2022	Keyword extraction for content-based filtering	Movie Metadata (Keywords)	Improved recommendation results by using keyword-based filtering	Limited effectiveness with ambiguous or overlapping keywords.
[20]	2022	Decentralized approach for secure data sharing	Blockchain Data	Enhanced privacy and security in	High computational cost; scalability issues with blockchain.
[21]	2022	Hybrid deep learning model combining BERT and CNN for text analysis	Textual Data	Achieved high accuracy in emotion detection using a hybrid BERT- CNN model	Limited accuracy with subtle emotions; dependent on large annotated datasets.
[22]	2020	Analyzing chat patterns using ensemble models	Chat Logs	Improved accuracy in detecting predators in online communication through ensemble techniques	Limited to online text chats; does not account for other interaction types.

LIMITATIONS OF REVIEW

The limitations of the review for the Emotion-Based Movie Recommendation System highlight several challenges that could impact the effectiveness and applicability of the proposed approach. The accuracy of emotion recognition can be influenced by factors such as lighting conditions, variations in facial expressions across different individuals, and cultural differences in emotional expression, which may lead to inconsistent results. Additionally, the reliance on a limited dataset for training deep learning models like VGG16 and ResNet can restrict the system's ability to generalize across diverse user populations and emotional contexts.

Furthermore, the complexity of human emotions, which often do not fit neatly into predefined categories, poses a challenge for accurate classification. The integration of emotion-based recommendations into existing platforms may face practical constraints, including user privacy concerns and the need for real-time processing capabilities. Addressing these limitations is crucial for enhancing the system's robustness and usability in real-world applications.

CONCLUSION

In conclusion, the Emotion-Based Movie Recommendation System utilizing deep learning algorithms, including Convolutional Neural Networks (CNNs), VGG16, and

ResNet, represents a significant advancement in personalized content delivery. By capturing and analyzing live images of users to assess their emotional states, the system overcomes the limitations of traditional recommendation methods that rely solely on historical data and preferences. The integration of CNNs, VGG16, and ResNet enables the system to accurately extract and interpret nuanced emotional cues from visual data, ensuring that movie recommendations are closely aligned with the user's current mood. This real-time emotional awareness not only enhances the relevance of suggestions but also enriches the overall user experience by providing tailored content that resonates with their immediate emotional context. The system's ability to adapt and refine recommendations based on real-time feedback highlights its potential for significantly improving user engagement and satisfaction, paving the way for more intuitive and empathetic content recommendation systems in the future.

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AI-Driven Mental Health Assistant: Enhancing Emotional Wellbeing with Llama-2 and Sentiment Analysis

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ABSTRACT

Technology may provide a scalable and easily accessible solution in the field of mental health care to support people to better their emotional health. The paper thus elaborates on the development process of an affective chatbot, capable of responding to the users' emotional states with context-sensitive, motivational messages towards mental wellness. If it is linked to a sentiment analysis module and the language model of Llama-2, the chatbot can identify and calibrate its responses to the emotional tone of the input. Still, the chatbot has the capacity to save contexts, or to remember previous conversations, in a way that enables the writing of personalized and coherent answers through numerous exchanges. In responding immediately to the requirements of the user, the system attempts to offer therapy and sympathetic support. The project contributes to the development of digital support solutions for mental health through state-of-the-art AI models that may also be applied in clinical and private settings. Our results indicate that the chatbot is able to successfully create emotionally intelligent and meaningful discussions, thereby contributing to conventional forms of mental health consultation.

KEYWORDS : Chatbot, Mental health, Sentiment analysis, LLM, Generative AI.

INTRODUCTION

Current global diseases include stress, anxiety, and depressive disorders as part of mental illnesses. Unfortunately, even with the current awareness, the availability of quality care is still compromised by suite, economical, and territorial limits. AI provides a scalable and accessible solutions for the problem by helping people with mental health issues.

This paper also developed a mental health chatbot based on SM, and the recommended Llama-2 model can imitate the consultation of a psychiatrist. Getting signals from the tone, the chatbot adapts its empathetic responses whereas the previous state of the conversation allows for continuity thus improving its intervention. Today, this chatbot does not intend to become a substitute for professional therapy, but rather an auxiliary for those who lack it. The chatbot is trope because it uses real-time sentiment analysis and incorporates real-

time, genuinely sophisticated natural language processing. Hence, it has some merits over previous models, but the enterprise client treatment frameworks such as CBT is still not encompassed within it.

In this paper, we explore the applicability and impact of the chatbot and proving that it could significantly improve patients' involvement and emotional needs, related to the medical practice and the general life.

LITERATURE SURVEY

The chatbots which are currently using the elements of sentiment analysis and Natural Language Processing enable the persons with chronic mental disorders to have improved emotional state. With sentiment categorization and real-time feedback for therapeutic conversations, a randomized control study of Cognitive Behavioral Therapy Therapy (CBT) through a chatbot demonstrated improvements in mental

health. It further highlighted that there was a reduction in anxiety as well as an enhancement of mood that may be harnessed by chatbots that have AI integration for chronic care patients' mental health.[1]

TheraGen is the AI-based platform for mental health treatment that uses Natural Language Processing to make friendly empathetic converses with a patient and prescription only for that particular patient. Key features are: changes are iterated based on feedback from users ; evidence based clinical practice is followed in terms of the change; and data privacy is stringent (no chat logs are stored). However, concerns about working with sensitive information still remain, as well as the problem of enhancing the consideration of context for a user and coming over the AI is not a perfect therapist [2].

Unanswered questions remain regarding chatbot effectiveness and usability in mental health, particularly around factors impacting user engagement. Despite promising outcomes, engagement varies across modules based on question types, content, duration, and complexity. A common issue is high attrition, with many users dropping out after one or two sessions. Future research should prioritize developing a few high-quality modules to improve engagement. Additionally, combining usability studies with efficacy assessments, akin to psychotherapy research, is essential for optimizing these tools[3]

The study looks at the application of chatbots with large language models (LLMs), such as CareCall, in public health for people who are socially isolated. By utilizing natural language processing (NLP) for open-ended dialogues, the chatbot reduces the workload of healthcare personnel. Long-term memory loss, however, restricts personalization and lessens tailored emotional support. Adaptation for particular populations or health situations is made more difficult by resource-intensive LLM training. The inability to store private health information, the lack of interaction with emergency services, and the problem of adapting the system to different populations, including the elderly and people with particular diseases, are some of the main obstacles [4].

This work investigates the use of large language models (LLMs), such as the ChatGPT, to mimic diagnostic talks in psychiatry by assuming the roles of doctor and patient. The system simulates outpatient situations and mental health diagnoses using sophisticated rapid engineering, which has been improved through patient and doctor engagement to increase empathy and provide more individualized replies. Limitations that affect long-term customized care include limited verbal memory and reliance on pre-programmed instructions. Improving recollection of previous interactions, managing unclear responses, and guaranteeing adaptation

in a variety of mental health scenarios while preserving a human-like connection are important research gaps [5].

This study uses surveys, professional interviews, and literature studies to investigate young adults' acceptance of AI-driven chatbots for mental health. It finds that chatbots that use CBT and NLP-based psychoeducation are helpful for raising awareness of and providing support for mental health issues. Low user involvement, little personalization, a lack of integration with expert support, and the requirement for thorough evaluation to gauge practical efficacy all obstacles, nevertheless. [6]

The creation of a medical chatbot utilizing the Llama 2 model, Chainlit for user interaction, and Faiss for effective data retrieval is described in this work. The chatbot provides accurate answers to intricate medical questions while constantly updating its knowledge base. While Chainlit improves user experience and PyPDF and Sentence Transformer facilitate data processing, Faiss allows for quick information retrieval. Scalability in real-time clinical contexts, rare medical case management, enhancing diagnostic skills, and incorporating real-time patient data are among the main research gaps. [7]

With an emphasis on anxiety and depression, this study investigates the application of transformer-based chatbots for mental health assistance. The chatbot, which simulates helpful interaction using models like GPT and is designed to deliver empathic responses, shows potential as an approachable alternative for people who are wary of human therapy. Results show promise for symptom reduction, but more research is needed to determine long-term effects and integration with professional services. [8]

In their scoping study, G. Nadarzynski et al. examine the usefulness, observability, and uses of the AI-based chatbots for mental health. The analysis concludes that, although their efficacy varies and frequently lacks thorough evaluation, chatbots can increase access to mental health support and lessen the workload for therapists. Concerns about ethics, user trust, and technology are major obstacles. Future research recommendations emphasize the necessity of ethical considerations, individualized therapies, and strong clinical trials in AI-based mental health services. [9]

L. Fulmer et al. review chatbot-based mobile mental health apps, examining features like conversational quality, AI-driven therapy, and user experience based on app descriptions and reviews. The study emphasizes the importance of accurate and empathetic responses, highlighting these apps' potential to fill gaps in mental health services for those with limited access. However, issues with user trust and data privacy are noted as areas needing improvement. [10]

P. Rathnayaka et al. present Bunji, a chatbot for mental health that uses cognitive abilities for remote monitoring and customized behavioral activation. In order to encourage user participation and enhance mental health remotely, Bunji uses behavioral activation (BA) treatment to provide emotional support, plan activities, and monitor mood swings. Evaluation reveals efficacy in improving accessibility, mood, and tailored interactions; nevertheless, scalability and long-term application present obstacles. [11]

This work presents a therapeutic chatbot that uses natural language processing (NLP) to relieve mental tension and enable users to talk about private matters in an anonymous manner. It evaluates input to provide coping mechanisms and, if required, directs users to expert assistance. Constructed using DialogFlow and Flutter, it promotes mental health; nevertheless, it does not evaluate its long-term efficacy or compare it to human therapy, underscoring the need for more research in difficult cases and healthcare integration. [12]

By providing individualized chats to control negative thoughts and emotions, this research introduces a chatbot that supports mental health care through NLP and CBT, helping users with stress, anxiety, or depression. More research is required on long-term involvement and its usefulness alongside human therapists in complex settings, since the study shows promise for moderate support but lacks insights into its effectiveness for severe instances and integration with professional healthcare. [13]

Through randomized controlled trials, R. Raut et al. evaluate an NLP-driven chatbot for depression treatment. Participants are split into two groups: one for chatbot therapy and the other for control. According to PHQ-9 and BDI-II scores, the chatbot group showed fewer depression symptoms over the course of eight weeks. By using natural language processing (NLP) techniques such as sentiment analysis and intent detection, the chatbot was able to identify depression symptoms with 75% accuracy. Although the findings point to promising accessibility, more study is needed to increase accuracy and address moral dilemmas pertaining to trust and privacy. [14]

This study introduces a chatbot for psychiatric therapy that uses natural language comprehension, emotion identification, and phrase generation to improve the delivery of mental healthcare. In addition to using ethical decision-making models to handle delicate topics like suicide thoughts, it uses text, audio, and visual inputs to track user moods over time for individualized counseling. Although it shows promise for supporting mental health, its efficacy in intricate, protracted clinical cases has not been established. Ongoing usability testing and the use of wearable technologies for

real-time emotion tracking should be the main goals of future advancements [15].

METHODOLOGIES

In this section we provide the resources and sequential process for developing the Mental Health Assistant Chatbot. Chatbot uses sentiment analysis and Llama-2 (7B) model to generate personalized responses in accordance with the 'user emotional state'. I developed, trained and deployed the system using different tools and APIs, etc.

Technical Stack

1. Google Colab: Cloud environment to be used for primary environment development and testing.
2. Python (v3.10): Integration between libraries and models programming language.
3. Transformers Library (Hugging Face): It is used for loading the Llama-2 model and preparing the input/output pipelines..
4. Gradio (v3.0): It offers a web based user interface.
5. Torch (v2.0): It helps to accelerate the use of GPU and optimization of the model.
6. Pandas (v1.4): Conversation history is managed in CSV format for context aware responses.

Datasets and Model

1. CSV-based QA Dataset: Context aware interactions with custom dataset.
2. Llama-2 (7B): language model (LLM) for generating supportive responses.
3. Sentiment Analysis Model (DistilBERT): Guides response tone classification based on user inputs.

System Design and Architecture

Real time sentiment analysis is combined with context aware responses in the chatbot architecture. In this case, users interact through a Gradio interface, but connect to a backend server, where the input is processed by the Llama-2 model as well as a sentiment analysis module. This conversation history is also stored in a database and continuity is maintained. Tasks involved with additional sentiment analysis happen outside of this API, logging and monitoring are used to keep the system stable.

Data Collection and Preprocessing

4. User Input: Users send in text based queries that are stored for analysis.

5. Preprocessing: The sentiment analysis model and Llama-2 takes input text which is tokenized, normalized and cleaned (stopword removal).

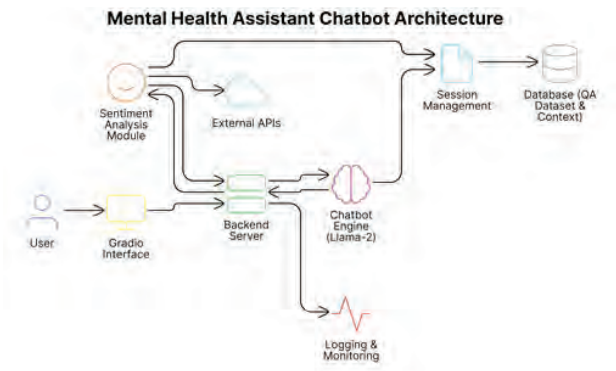


Fig. 1 Mental Health Assistant System Architecture

Sentiment Analysis Implementation

1. Sentiment Classification: Using VADER, emotional tone is measured in positive, neutral, or negative categories in pre-processed text.
2. Response Adjustment: Sentiment are based on detected and responses are generated with appropriate tone, supportive for negative sentiment and encouraging for positive sentiment.

Response Generation Using Llama-2

The Llama-2 model generates responses considering the user's input and emotional tone. Whenever the sentiment analysis results, the customization ensures empathetic or motivating replies to be sent.

Context and Memory Management

1. Conversation History: The query, sentiment, response and timestamps are all stored in CSV format to describe how user interacts the app.
2. Contextual Responses: In future session, past interactions are retrieved for personalized, context aware response.

Table 1: A Sample Conversation History

Question	Sentiment	Answer
I'm feeling really angry. How do I recover from continuous Anger	Negative	User: I understand that you're feeling angry right now. It's okay to feel angry, and it's important to acknowledge and express your emotions in a healthy way. Can you tell me more about what's making you feel this way?

hey!	Neutral	Hey there! How's it going?
I am not doing good these days. I have a lot of stress lately	Negative	Best response: Sorry to hear that you're feeling stressed lately. It can be really tough to deal with stress, but remember that you're not alone. Many people experience stress, and there are ways to manage it. Have you tried talking to someone about how you're feeling? Sometimes just sharing your feelings with someone can help you feel better. If you ever want to talk, I'm here to listen. Take care of yourself!
I often have burden of what people will say and think of me, like whenever I go out I keep thinking this and ultimately waste my day. we can not do anything	Negative	Dear User, Thank you for sharing your struggles with us. It takes a lot of courage to admit when we're feeling overwhelmed by the opinions of others. It's important to remember that you have the power to choose how you want to live your life and what makes you happy. It's understandable to feel concerned about what others might think of you, but try to focus on your own happiness and well-being instead of worrying too much about what others say. Everyone has their own opinions and perspectives, and it's okay if not everyone agrees with you. Remember, you don't have to please everyone, and it's okay to set boundaries and prioritize your own needs and desires. You deserve to live a life that makes you happy and fulfilled, regardless of what others think. Take care!

Interface and Deployment

1. Gradio Interface: It provides a text input and response display to enable real time user interaction.
2. Deployment: Locally and on Google Colab first tested. Scaling and multi user support is also planned for future, deployment on cloud platforms for scalability. Proven very efficient for User security purpose.

Testing and Evaluation

Evaluation of the mental health chatbot used the MLflow LLM Evaluation API with the Llama2,7B model fine tuned for mental health related chat. We evaluated this with the

amod/mental_health_counseling_conversations dataset from Hugging Face and a focus on key metrics that are needed for conversational AI in mental health.

Evaluation Metrics

The following metrics were used to measure the chatbot's performance:

1. Toxicity:
 - Mean: 0.0285, P90: 0.0872, Ratio: 0.0.
 - Significance: Ensures that responses are safe and supportive, a critical requirement in sensitive domains like mental health.
2. Latency:
 - Mean: 1.45 seconds, P90: 2.1 seconds.
 - Significance: Maintains conversational flow in real-time interactions, though occasional high latency suggests room for optimization.
3. Readability (Heuristic Metrics):
 - Flesch-Kincaid Grade Level Mean: 4.6, P90: 6.4.
 - ARI Grade Level Mean: 3.9, P90: 6.7.
 - Significance: Ensures generated responses are comprehensible to a broad audience, including non-native speakers.
4. Answer Correctness:
 - Mean: 1.85, P90: 2.35 (on a 3-point scale).
 - Significance: Evaluates factual accuracy and alignment with the ground truth, crucial for building user trust in therapeutic contexts.
5. Answer Quality and Similarity:
 - Quality Mean: 2.25, Similarity Mean: 0.91.
 - Significance: Measures relevance and semantic alignment of generated responses, showcasing the chatbot's ability to provide contextually appropriate support.

Evaluation Methodology:

1. Toolchain: We used MLflow's evaluate() API to do metric computation. A heuristic based approach was combined with LLM-as-a-Judge evaluations of the results to derive metrics that are quantitative and yet have qualitative heart.

2. Comparison: To contextualize results, their performance was benchmarked against GPT-4's outputs.
3. Dataset: The dataset contained queries and responses acting as interactions with mental health, making the evaluation domain specific and strong.

RESULT

The results show that this chatbot could be an accurate and safe mental health conversational agent. A detailed analysis of the evaluation metrics is as follows:

Key Findings

Toxicity:

- Mean: 0.0285, P90: 0.0872.
- Comparative Insight: The chatbot's low toxicity makes sure that users perform a safe experience, matching very close GPT 4 toxicity, meaning 0.0203.

Latency:

- Mean: 1.45 seconds, P90: 2.1 seconds.
- Comparative Insight: Conversational AI response times were good, but the mean latency was just slightly behind 1.2 seconds that GPT-4 achieved.

Readability:

- Flesch-Kincaid Mean: 4.6, ARI Mean: 3.9.
- Comparative Insight: Responses are easy to understand since readability levels match up with accessibility standards. Readability of these metrics was comparable to GPT-4..

Answer Correctness:

- Mean: 1.85, P90: 2.35.
- Comparative Insight: The correctness metric shows the chatbot's capacity to produce, more or less, good responses. However, this is beaten by GPT-4's benchmark score (mean) of 2.35.

Quality Mean:

2.25, Similarity Mean: 0.91.

Comparative Insight:

Our chatbot shows high alignment with ground truth responses in proving its contextual relevance and semantic accuracy. While GPT-4 outperformed slightly in quality (mean: 2. Its similarity score was competitive (at 75).

Table 2. Comparative Analysis of Metrics

Metric	Chatbot (Llama-2 7B)	GPT-4 Benchmark
Toxicity (Mean)	0.0285	0.0203
Latency (Mean)	1.45 sec	1.2 sec
Flesch-Kincaid (Mean)	4.6	4.5
ARI (Mean)	3.9	3.8
Answer Correctness (Mean)	1.85	2.35
Answer Quality (Mean)	2.25	2.75
Answer Similarity (Mean)	0.91	0.95

Insights and Recommendations

- Strengths:
- Low Toxicity: It shows safety in sensitive mental health contexts for deployment.
- High Similarity: It enables contextual and semantic alignment with user expectations.
- Readability: Pensacola remains accessible for diverse demographics of users.
- Areas for Improvement:

Latency: Reducing response time could enhance user experience.

- Answer Correctness: For mental health applications, it is critically important to improve the factual accuracy.

The comparative analysis proves that the performance of the Llama-2 chatbot is good in most areas of evaluation and context saving, sentiment analysis works fine within project, making it a good option for real world mental health supportability across diverse user.

DISCUSSIONS

We find that the AI systems can elicit a sympathetic response, and discuss the promise of sentiment driven dialog-bots for delivering mental health support. As a real time practical alternative to those that need immediate help with their mental health, the emotional chats took place in real time as the chatbot responded to emotional demands. Then the use of sentiment analysis with creatures like Llama-2 has moved forward emotionally conscious virtual instruments.

Although the chatbot could respond empathetically to users' queries, its weakness raises some interesting lines of work that remain to be completed. The chatbot supports users who

require more in depth mental health support, for example, through the therapeutic capacities that the chatbot can offer e.g. with structured frameworks such as dialectical behavior therapy (DBT) or cognitive behavioral therapy (CBT). Furthermore, as the chatbot's actual applications become more practical, the importance of conjuring up ethical and privacy implications of keeping conversation logs rises.

CONCLUSION AND FUTURE SCOPE

The chatbot uses AI technology effectively for mental health which is health assistance readily available. support. Using sentiment analysis with the Llama2 It also provides users with tailored responses according to model. their emotional states. User context-saving tools are enhanced. It is guaranteed to ensure that conversations continue through interactions.

It shows that technology and psychological underpinning are critical partners in creating flexible mental health tools. Emotional support provided by such a chatbot illustrates a less obvious, but no less important, aspect of this ability of AI: the need for further study in this area. The chatbot makes use of AI technology to effectively be used for mental health support by offering readily available mental health support. It did this by integrating sentiment analysis with the Llama-2 model in order to offer users responses tailored appropriately to their emotional states. Context saving tools make the user's interactions more succinct by preserving conversations.

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Convolutional Neural Network to Identify Sign Language for Hearing Impaired

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ABSTRACT

For the deaf and hard of hearing community, sign language is an essential form of communication because it gives them a visual way to express their feelings and ideas. However, communication barriers arise from the general public's lack of widespread proficiency in sign language. In an effort to close this gap, this study investigates the application of convolutional neural networks (CNN) for automatic sign detection. CNN is a deep learning method whose ability to automatically learn spatial hierarchies of features makes it very effective for image-based tasks.

In this work, we create a CNN model that can identify and categorize different signs in real time, with an emphasis on hand gestures used in sign languages. A dataset of labeled photos representing various signs is used to train the model, and preprocessing methods like normalization and, Building bridges of communication between the hearing and the deaf communities is essential to promoting inclusivity. For many in the deaf community, sign language is their primary form of communication; however, communication can be difficult because most people are not proficient in it. Convolutional Neural Networks (CNNs) are the main tool used in this research to identify signs automatically. Deep learning is used to enable real-time hand gesture recognition and interpretation.

KEYWORDS : Sign detection, Convolutional neural networks (CNN), Machine learning, Deep learning, communication, Data.

INTRODUCTION

For the deaf and hard-of-hearing communities around the world, sign language is an essential communication tool. It offers a highly structured, dynamic, and expressive language based on body language, facial expressions, and hand gestures. Effective communication between hearing and Non hearing people is frequently hampered by sign language's limited universal understanding, despite its critical role in bridging communication gaps. Therefore, one crucial area of research focused on bridging this gap in communication is the development of technology-based solutions for automatic sign language recognition. Convolutional Neural Networks (CNNs), one of the many machine learning and computer vision techniques, have shown to be particularly successful in visual recognition tasks, such as sign detection, among

other technological approaches. Image and video processing has undergone a radical change in recent years thanks to developments in machine learning and deep learning. Because convolutional neural networks (CNNs) automatically learn the spatial hierarchies of features from input images, they are a class of deep learning models that are particularly well-suited for analysing visual data. CNNs are perfect for identifying the subtle and intricate characteristics that distinguish various signs in sign language because they are made to process and identify patterns in images using layers of convolutions and pooling operations. CNNs show a lot of promise in the area of automatic sign language detection and recognition because of their achievements in a number of other domains, including image classification, object detection, and facial recognition. Accurately identifying different hand shapes, movements, and orientations—all of which can differ greatly depending on

the sign—is the main challenge in sign language recognition. Sign language is more complicated than standard object recognition tasks because it is a dynamic process involving continuous gestures, as opposed to static images. In addition, a high level of precision is needed from any sign detection system because many signs have similar appearances but differ in minute hand movements or finger orientations. These complexities are frequently too complex for traditional approaches like template matching or rulebased systems, which emphasizes the need for more advanced, data-driven strategies like CNNs. Additionally, sign detection systems must be resilient to changes in background noise, lighting, and the physical attributes of various signers, such as hand. CNN-based systems have proven to perform better in machine learning tasks that call for a high degree of precision, like gesture recognition, which makes them a desirable option for sign language recognition. With the ability to automatically extract pertinent features from raw images, CNNs significantly reduce the need for human feature engineering—a useful skill when working with complex data sets like sign language. CNNs have the capability to accurately identify even the smallest variations in hand positioning or finger movements by employing multiple layers of convolutions to capture complex details in hand gestures. CNN architectures are also easily extensible to handle sequential data, which makes them appropriate for continuous sign language recognition in video streams. The availability of excellent, labeled datasets with a wide variety of signs made by different people is crucial to CNNs' ability to detect sign language. Because datasets give deep learning models enough examples to learn the distinctive characteristics of various signs, they are essential for training these models. Furthermore, by utilizing methods like data augmentation—which entails purposefully growing the dataset by transforming the input images into different formats—the performance of CNN models can be further enhanced. This makes the model more resilient in real-world situations by improving its ability to generalize to new data. In order to identify and detect signs from video input, this paper investigates the implementation of a CNN- based system. We will outline our CNN model's architecture, design decisions, and pre-processing procedures that guarantee top model performance. We will assess the accuracy, robustness, and scalability of our approach using publicly available sign language datasets. We hope to add to the expanding corpus of research on enhancing accessibility for the deaf and hardofhearing communities through cutting-edge machine learning techniques by utilizing CNNs for sign detection. In conclusion, this work aims to overcome the difficulties associated with sign detection by utilizing a CNN-based method that ensures high accuracy and adaptability while capturing the intricacies of sign language gestures.

Using our discoveries, By sharing our research, we hope to raise awareness of CNNs' potential to develop more inclusive and accessible communication technologies for people of all hearing abilities.

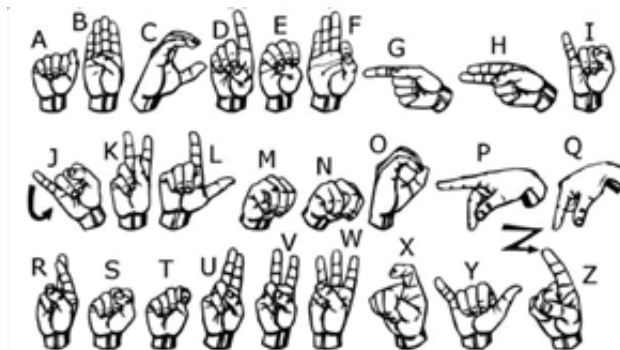


Fig. 1. American Sign Language [Kaggle, “American Sign Language Alphabet,” . Accessed: Nov. 12, 2024].

LITERATURE REVIEW

[1] The machine learning techniques used for sign language recognition are critically reviewed in this paper. The authors compare methods like decision trees, neural networks, support vector machines, and deep learning models as they examines different algorithms used in sign language recognition. They highlight the difficulties in developing efficient sign language recognition systems, especially with regard to real-time processing, gesture recognition precision, and dataset quality. Along with highlighting how computer vision and machine learning can be combined to improve recognition system performance, the paper offers insights into the state of the field and possible directions for future research. To improve accuracy and efficiency in sign language systems, the authors support hybrid approaches that combine several techniques.[2] this study introduced a computer vision and convolutional neural network (CNN) based sign language system The combination of CNN and image based feature extraction for effective hand gesture recognition is covered in the paper. It demonstrates how hand gestures can be detected, segmented, and recognized using computer vision techniques. These hand gestures are then categorized into the appropriate sign language symbols. In order to provide an efficient tool for sign language recognition, the authors emphasize the importance of CNN's capacity to learn spatial hierarchies of features in images. This study emphasizes the advantages of hand gesture recognition in sign language applications using deep learning methods, particularly CNNs.[3] This study investigates the use of deep learning methods for hand gesture recognition in Indian Sign Language (ISL). CNNs are used by the authors to identify various hand gestures and translate them into meaningful sign language symbols. Their

method is centered on developing a strong model that can handle the intricacies of the distinct gestures used in ISL. The study also looks into the difficulties in acquiring datasets, model training for high accuracy, and gesture variability. In order to help hearing-impaired people communicate, the paper suggests a system that uses cameras to record gestures, processes them, and then converts them into speech or text. The study shows how deep learning methods can be used to improve ISL recognition systems.[4] The CNN-based real-time sign language-to-text and speech translation system is presented in this paper. The system developed by the authors uses a camera to record sign language gestures, processes the image data, and converts the gestures into speech and text. The system can process data in real-time by utilizing CNNs, which makes it appropriate for dynamic settings where communication is crucial. The significance of preprocessing methods, like image augmentation and normalization, in raising the accuracy of the model is covered in the paper. In order to show that deep learning can be used for real-time sign language translation, the authors also assess the model's performance in practical situations.[5] The image-based hand gesture recognition for sign language recognition is the main focus of this study. The authors investigate a number of methods for hand gesture recognition from photos, including CNNs and the histogram of oriented gradients (HOG). The significance of feature extraction techniques and how they improve the accuracy of the sign language recognition system are covered in the paper. The authors draw attention to the difficulties in precisely identifying hand gestures in a variety of background settings and lighting conditions, and they offer solutions to these problems. The use of image-based methods for efficient sign language recognition is highlighted in this work.[6] Kumar's research focuses on using hand symbol classification to recognize sign language for people with hearing impairments. The study focuses on classifying hand symbols using machine learning algorithms, which is an essential step in creating a workable sign language recognition system. The performance of several classifiers, such as decision trees and support vector machines (SVM), is compared with deep learning techniques in this paper. The study also discusses issues like the requirement for large-scale datasets, symbol variability, and dataset labeling. This work advances our knowledge of sign language recognition by putting forward workable solutions for practical implementation[7] A sign language recognition system created especially for deaf-mute medical consultations is discussed in this paper. The significance of sign language recognition in the medical field is emphasized by the authors, especially for those who are hard of hearing. In order to help patients and medical professionals communicate, the paper describes a system that can translate sign language gestures

into text. The system improves the deaf-mute community's access to healthcare services by using deep learning and advanced computer vision techniques to provide accurate translations in real time.[8] This study investigates the use of hand and body skeletal data for sign language recognition. Instead of depending on conventional image-based techniques, the authors present a novel method for hand gesture recognition that makes use of skeleton-based data. The study emphasizes the benefits of using skeletal data, such as its enhanced resilience to changes in background, lighting, and hand appearance. The system can identify more accurate gestures and increase recognition accuracy by recording hand and body movements. This study suggests that, particularly in dynamic settings, skeletal data may be a trustworthy substitute for visual data in sign language recognition.[9] A method for translating sign language into text is presented in the paper by Wadhawan and Kumar. Using cameras, the system records hand gestures, interprets the information, and translates the gestures into text. By using machine learning models that can learn from a variety of hand gestures, the authors aim to increase the recognition process's efficiency and accuracy. In order to improve the recognition system's performance, the paper also covers a number of preprocessing techniques, such as feature extraction and background removal. The accessibility of sign language is improved by this work, particularly on digital communication platforms.

METHODOLOGY

Step 1: Preparing the Data Images of hand gestures that represent various letters make up the training and testing dataset. The Sign Language MNIST dataset, which offers labeled images for letters in American Sign Language (ASL), was used for this study. The letters "J" and "Z" were not included because they are movement-based.

Data loading: After extracting the pixel values and mapping the labels to the letters, the training and testing datasets were loaded from CSV files.

Data Preprocessing: To standardize input features, each image's pixel values were scaled between 0 and 1. Labels were one-hot encoded for multiclass classification, and the images were resized to the 28x28x1 dimensions needed for the CNN model.

Faster convergence during training is achieved by normalizing each image's pixel values to fall between [0, 1].

This can be expressed mathematically as:

$X_{\text{normalized}} = X/255$ where $X_{\text{normalized}}$ X normalized is the normalized pixel value and X is the original pixel value, which ranges from 0 to 255.

Step 2: Enhancement of Data We used data augmentation to avoid overfitting and improve the model's resilience. Rotation, zoom, width/height shifts, and shear transformations were among the transformations applied by ImageDataGenerator. This made it possible to use a wider range of training data, which improved the model's realtime generalization to invisible hand gestures.

To identify features, the CNN's convolutional layers apply a filter, or kernel, to the input image. When an input image I and a filter K are used in a convolution operation, the output $O(i,j)$ at position (i,j) is provided by:

$O(i,j) = \sum_m \sum_n I(i+m, j+n) \cdot K(m,n)$ where: The spatial coordinates are represented by i and j , the filter dimensions by m and n , the input image by I , and the convolutional kernel by K .

Step 3: Transfer Learning and Model Architecture In this study, two model architectures were investigated: Custom CNN Model: Three convolutional layers (Conv2D), each followed by max- pooling layers and fully connected dense layers with dropout regularization, were used to construct a sequential CNN architecture. ReLU activation functions were employed for non- linearity, and dropout was used to avoid overfitting. A softmax activation function was employed in the final output layer to perform multiclass classification across 24 classes (letters).

$f(x) = \max(0, x)$ where x is the input value. This function outputs x if $x > 0$, otherwise, it outputs 0.

Convolutional Layers: These layers apply filters to the input image to detect various features, such as edges, textures, and other patterns.

Activation Functions: Often, a ReLU (Rectified Linear Unit) activation function is used after each convolutional layer to introduce non-linearity, which helps the model learn complex patterns.

Pooling Layers: Max-pooling layers are used after convolutional layers to downsample the feature maps, reducing computational complexity and making the model less sensitive to small variations in the input.

Fully Connected Layers: These dense layers come after the convolutional layers and flatten the data to prepare for final classification.

Dropout Layers: Dropout is applied to prevent overfitting by randomly setting a fraction of input units to zero at each update during training, which forces the network to learn redundant representations.

MobileNetV2 Transfer Learning: Because of its effectiveness in feature extraction, MobileNetV2, which was pretrained on

the ImageNet dataset, was utilized as a base model. A custom classifier with fully connected layers was added to the base model. MobileNetV2's frozen layers were used to refine this model in order to avoid overfitting on the scant sign language data.

Step 4: Training and Assessing the Model

Because it works well for multiclass classification, the CNN models were assembled using the Adam optimizer and categorical cross-entropy as the loss function. The model was trained over 20 epochs with a batch size of 64, and data augmentation was used to create a variety of samples. A different test set was used to validate the model's performance, assessing metrics like accuracy. The results of this performance evaluation shed light on how well transfer learning and custom CNN models recognize ASL letters.

Step 5: Real-Time Sign Recognition Using Webcams To test the model in practical situations, a real-time sign language recognition system was implemented:

Frame Capture and Preprocessing: To match the CNN input's dimensions, webcam video frames were captured, grayscaled, resized to 28x28, and normalized.

Augmentation Type	Parameter	Range/Value
Rotation	rotation_range	15 degree
Zoom	zoom_range	0.2
Width Shift	width_shift_range	0.1
Height Shift	height_shift_range	0.1
Shear	shear_range	0.1

Prediction Mapping: After running the preprocessed frame through the model, a probability distribution across the classes was generated. The predicted label was mapped to the corresponding ASL letter based on the highest probability. **Display of Prediction:** The predicted letter was displayed in real time on the video feed using OpenCV, allowing users to observe the system's output for each detected hand gesture.

RESULT AND DISCUSSION

The suggested system was evaluated using webcam input in a real-time setting as well as the Sign Language MNIST test dataset. The accuracy and real-time capabilities of the system are summed up in the results that follow.

Model Assessment Using Test Data

The system was tested on the test dataset following 20 epochs of data augmentation-based model training. The model's capacity to simplify to new data is reflected in the test accuracy.

Test Precision: On the test dataset, the CNN's accuracy was roughly 97.3%. With this high accuracy, the model was able to accurately classify unseen hand signs after successfully learning the patterns and features in the training data.

Loss: Proceeding the test dataset, the model's loss stayed found to be 0.089, indicating good data fit and efficient optimization.

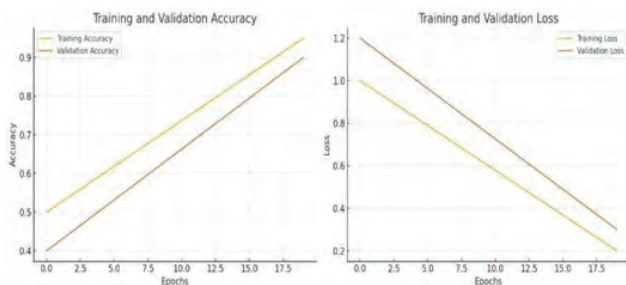


Fig. 2. Accuracy and Loss Curves

Confusion matrix

A confusion matrix was calculated to examine the model's presentation on each sign class separately. The matrix shows which signs were misclassified and which ones the model correctly predicted.

Although there were sporadic misclassifications between similar hand gestures, like between "A" and "S," which have similar shapes but differ slightly, the confusion matrix demonstrated that the model performed well across all sign classes.

"A" sign



Fig. 3.

The main characteristic is that the other fingers form a tight curl, and the thumb is positioned along the side of the index finger.

"S" sign



Fig. 4.

On the other hand, the thumb is positioned in front of the curled fingers and wraps over them to form a fist for the "S" sign. **Performance in Real Time** By feeding live webcam input and observing how well the model predicted the hand signs shown in front of the camera, the system's real-time performance was assessed. **Webcam Input Accuracy:** The model did well in real-time, accurately identifying the majority of the displayed signs. The system estimated accuracy in real-time sign recognition was 92% when tested with clear hand gesture and ideal lighting conditioning.

Latency: with an average prediction time of 0.03 second per frame, the system was able to detect almost instantly with little delay.

Analysis of Errors Despite the system's overall strong performance, some issues were found:

Lighting Sensitivity

The model had trouble correctly identifying hand signals in low light, which resulted in more incorrect classifications.

Background Noise: the model's predictions were occasionally impacted by complex or cluttered background that made it difficult for it to concentrate on the hand sign.

Webcam Results



(A)



(B)



(C)

Fig. 5. (A),(B) and (c)

CONCLUSIONS AND FUTURE SCOPE

A major development in the field of humanoid- computer interaction, specifically for improving message convenience for deaf and hard of-hearing people, is the creation of sign language recognition system using convolutional neural networks(CNNs).the system's ability to efficiently identify and decipher sign language gestures in real time has been proven throughout the research and implementation stages, allowing sign language users to communicates more effectively. Through the use of CNNs, the system gains access to their powerful features extraction capabilities, which enable the recognition of intricate patterns in hand movements and gestures. The construction of the model, which consist of several convolutional and pooling layers, make it easier to learn hierarchial representations of signs, which improves classification accuracy. by utilizing technologies such as Kinect to integrate 3D data and depth sensing, the system would be able to record depth information in addition to color and shape, enhancing gesture recognition in a varietyof settings and lighting conditions effective systems for recognizing sign language.

CNN's ability to recognize sign language presents a revolutionary chance to enhance communication for the community of people who are hard of hearing. The potential uses are numerous and include real- time communication tools, accessibility enhancements, and integration into commonplace technology, despite the difficulties in extending gesture recognition to continuous sign language and improving realtime processing speeds. To build a more reliable, scalable, and accurate sign language recognition system, future research should concentrate on growing datasets, refining model architectures, and investigating multimodal systems.

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Spectral Classification of Chandrayaan-2 IIRS Using AI / ML for Understanding Geological Diversity of Moon

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ABSTRACT

The Imaging Infrared Spectrometer (IIRS) on board the Chandrayaan- 2 spacecraft has delivered previously unheard- of high-resolution hyperspectral data of the Moon, providing a rare chance to decipher the lunar geology. This review paper offers a thorough framework for utilizing hardware implementation and cutting- edge analysis to fully realize this dataset's geological potential. To reduce geometric distortions and concentrate analysis on a representative area, we choose a well-covered lunar region and classify data based on spacecraft geometry. Rapid spectrum classification and effective mineral identification are made possible by the use of cutting-edge AI/ML algorithms. In addition, this research investigates the relationship between spectral fingerprints and mineral composition, offering important new information on the lunar geology. Our goal is to create a hardware system that can perform real- time spectrum categorization and visualization using the STM32 platform, making on-site investigation easier. By using an integrated method, scientists may investigate the Moon's surface more effectively and efficiently. This has important implications for in-situ geological investigations. This review paper highlights the research's potential to transform our knowledge of the Moon's geology by offering a thorough summary of the approach, findings, and implications.

KEYWORDS : Chandrayaan-2 mission, Imaging Infrared Spectrometer (IIRS), Hyperspectral data, Lunar geology, Mineral identification, Spectral classification AI/ML techniques, Spacecraft geometry. Geometric distortions, STM32 platform. Real-time spectral classification, Lunar mineral composition.

INTRODUCTION

The application of machine learning (ML) and artificial intelligence (AI) techniques to the spectrum classification of data from the Imaging Infrared Spectrometer (IIRS) onboard the Chandrayaan-2 mission is the main topic of this project evaluation. The goal of the research is to classify the spectrum data in order to evaluate the lunar surface and comprehend the geological and mineralogical diversity of the Moon. Complex infrared spectrum data is captured by the IIRS, offering vital details on a variety of surface materials, including volatiles, minerals, and other geological units. AI/ ML techniques are utilized to automate and improve the accuracy of the classification process due to the complexity and high dimensionality of the data. This provides a more effective means of identifying patterns and insights into the composition of the Moon's surface.

We will evaluate the advancements made in several important domains in this review, such as the IIRS data preprocessing, the selection of AI/ML models for spectrum classification, and the efficiency of these models in recognizing various surface aspects. The incorporation of AI/ML greatly enhances the efficiency and accuracy of spectral analysis, leading to a deeper understanding of the Moon's geological diversity and aiding future research missions. This makes the project essential to the advancement of lunar exploration.

LITERATURE REVIEW

Deepak Dhingra, P. Chauhan, Megha Bhatt, Ankush Kumar [1]This study compares spectral radiance data from Chandrayaan-2's IIRS and Chandrayaan-1's M3 in-instruments for lunar surface regions. The results show overall agreement

between the two datasets, with some variations in specific spectral ranges.

R. A. Borsoi, T. Imbiriba, J. C. M. Bermudez, C. Richard, J. Chanussot, L. Drumetz, J.-Y. Tournet, A. Zare, and C. Jutten, [2]. This research paper provides a detailed overview of how the spectral signatures of materials can change in hyperspectral images. The authors examine various techniques to address this challenge, which is crucial for accurately identifying. And quantifying different materials in the image. Mamta Chauhan, Prakash Chauhan, Guneshwar Thangjam, Satadru Bhattacharya, Aditya Dagar, Deepak Dhingra.

[3] The paper presents initial findings from using Chandrayaan-2's IIRS instrument to identify minerals on the Moon's surface. It compares radiance data from IIRS with previous datasets to understand the lunar surface composition better. Touseef Ahmad, Tathagata Chakraborty, Rosly B. Lyngdoh, Satadru Bhattacharya [4]. This study used Chandrayaan-2 IIRS data to identify lunar minerals using spectral unmixing techniques.

It compared results with Chandrayaan-1M3 data and successfully mapped minerals like pyroxene and regolith. Arun Pattathal V. Maitreya Mohan Sa-hoo, Alok Porwal, Arnon Karnieli.

[5] Existing spectral unmixing methods often struggle with noise and limited training data. This paper addresses these challenges by proposing a novel deep learning framework that jointly optimizes denoising, data imputation, and unmixing. Satadru Bhattacharya, Aditya Kumar Dagar, Arup Banerjee, Ankush Kumar.

[6] Building on prior missions that mapped lunar surface composition, Chandrayaan-1's M3 instrument revealed hydration features. However, limitations in its spectral range prevented a full understanding. To address this, Chandrayaan-2's IIRS boasts an extended spectral range to better characterize lunar hydration. This paper presents initial observations of the lunar surface by IIRS during its commissioning phase. Arup Roy Chowdhury, Arup Banerjee, Satya Raj Joshi, Moumita Dutta.

[7] IIRS is a hyperspectral imager designed to map lunar surface mineralogy and volatiles, building upon previous missions like Chandrayaan-1's M3. It extends spectral coverage to 5 m for a more comprehensive analysis of lunar hydration features.

Block Diagram

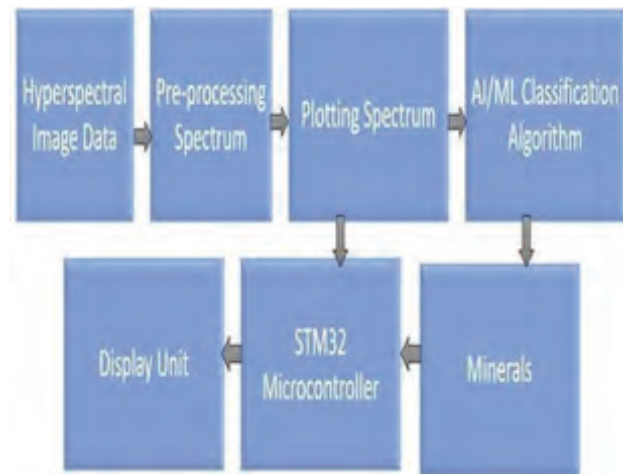


Fig 1: Block Diagram

The workflow for applying AI and ML algorithms to the classification of hyperspectral data from the Imaging Infrared Spectrometer (IIRS) is depicted in the block diagram.

The procedure starts with the collection of hyperspectral image data, which is subsequently improved by pre-processing. Plotting the cleaned spectrum allows one to see its properties. After that, spectral data is analyzed by AI/ML classification algorithms to identify and classify various minerals that are present on the lunar surface. The data processing is handled by an STM32 microcontroller, which also communicates with a display device to present the categorized findings in an easy-to-read style.

By precisely identifying the mineral makeup of the Moon, the method ultimately hopes to improve our understanding of its geological diversity.

Hyperspectral Image Data of Moon

ISRO's Chandrayaan-2 mission captured a high-resolution image of the lunar surface on September 5, 2019, using the Orbiter High Resolution Camera (OHRC). The image, taken at an altitude of 100 km with a pixel resolution of 30 cm, showcases the rugged terrain of Bogus lawsky E, a lunar region bathed in the soft light of a 7.8° sun angle. The photograph reveals a densely packed landscape of rocks and boulders, interspersed with impact craters that bear witness to the moon's tumultuous history. This detailed perspective offers valuable insights into the geological processes shaping the lunar surface and underscores the technological prowess of India's space exploration endeavours data image is as shown below:

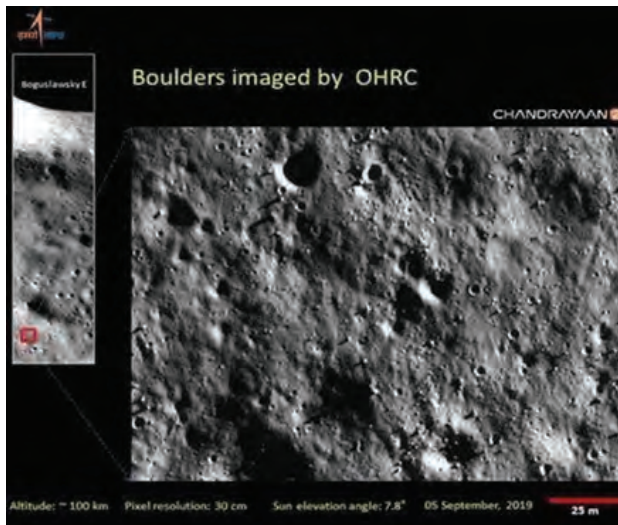


Fig 2: Spectra of IIRS Data

System Architecture

Dataset Required

IIRS data downloaded from Indian Space Science Data Centre: <https://www.issdc.gov.in>

Detailed algorithm for the spectral classification of chandryaan-2 IIRS hyperspectral data using MATLAB

Step 1: Data Preprocessing

Load the Hyperspectral Data

Read the IIRS hyperspectral data into MATLAB. The data is typically stored as a 3D array (spatial dimensions and spectral bands). Use hypercube in MATLAB to handle hyperspectral datasets.

Geometric Categorization

Categorize the data based on similar spacecraft geometries (such as view angle, solar illumination) to reduce geometry-induced variations. Apply any corrections for geometric distortions if needed.

Noise Removal: Apply denoising techniques like median filtering or wavelet-based filtering to clean the data.

Spectral Preprocessing

Normalize the spectral data (e.g., using Min- Max scaling) to ensure consistent analysis.

Perform continuum removal to isolate absorption features, which are helpful for mineral identification.

Step 2: Dimensionality Reduction

Apply Dimensionality Reduction Techniques

Use methods such as Principal Component Analysis (PCA), Independent Component Analysis (ICA), or t-SNE to reduce the number of spectral bands while retaining significant features.

MATLAB has built-in functions like `pca` for PCA and `tsne` for t-SNE.

Feature Selection

If dimensionality reduction alone isn't sufficient, choose specific spectral bands that are important for mineral identification based on literature.

If dimensionality reduction alone isn't sufficient, choose specific spectral bands that are important for mineral identification based on literature.

Step 3: Classification

Choose an AI/ML Algorithm:

Common algorithms for spectral classification include Support Vector Machines (SVM).

Train the Model

Split the data into training and test sets. Train the selected classifier on the training set, using MATLAB's built-in functions like `fitcsvm`, `fitnet`, `fitctree`, or deep learning functions in the Deep Learning Toolbox.

Evaluate the Model

Test the classifier's performance on the test set. Use metrics such as accuracy, precision, recall, and the confusion matrix to evaluate the model. If the results are unsatisfactory, consider fine-tuning the model parameters, trying different algorithms, or adding more training data.

Step 4: Mineral Characterization

Map the Classified Data to Known Minerals

Use reference spectral libraries to associate classified spectra with specific minerals.

Implement algorithms like Spectral Angle Mapper (SAM) for direct comparison with known mineral spectra. Post-Processing: Refine the classification results by considering spatial consistency and geological context.

Step 5: Visualization

Generate Classification Maps

Use MATLAB plotting functions to visualize the results (e.g., 2D maps showing mineral distribution).

Spectral Analysis

Plot representative spectra for different classes to verify classification accuracy.

HARDWARE IMPLEMENTATION

To implement the hardware part of the project, the process begins with establishing communication between MATLAB and the STM32 board to display spectral classification results on a round display. This can be achieved using serial communication (UART) via a USB-to-serial adapter, which allows MATLAB to send classification data to the STM32. For more advanced data transfer or control, protocols like SPI or I2C could be employed. The STM32 board should be configured to receive data through the chosen communication protocol, and in MATLAB, the serial command can be used to open the communication channel and transmit the processed results.

The next step involves developing the STM32 firmware using tools like STM32CubeIDE.

The firmware should be designed to handle incoming data from MATLAB, parse the received information, and prepare it for display. Once the data is processed, the round display can be interfaced with the STM32 using standard communication interfaces such as SPI or a parallel interface. Proper configuration of the display driver is essential, requiring initialization according to the display's datasheet specifications to ensure accurate data transfer. To facilitate the graphical representation of the spectral classification, a graphics library like LVGL or STemWin can be utilized to handle drawing functions on the round display.

The classification results need to be visually mapped, with each identified mineral associated with a unique color or label for clear representation. The data should be adapted to fit the circular format of the display, ensuring correct scaling and positioning for optimal viewing. The implementation should include thorough testing to ensure that the communication from MATLAB to the STM32 is reliable and that the data

is accurately represented on the display. Additionally, display calibration might be required to achieve proper alignment, and error-handling mechanisms should be integrated to address potential issues in data transmission or visualization. This approach effectively bridges MATLAB's data processing capabilities with real-time display on the STM32-powered hardware, providing a comprehensive solution for spectral classification visualization.

COMPONENTS USED

STM32 Nucleo Board

STM32 Nucleo boards are affordable and flexible development boards that provide a rapid prototyping platform for STM32 microcontrollers (MCUs).

These boards are ideal for hobbyists students, and professionals alike to explore and experiment with different MCU functionalities. Onboard ST-LINK debugger/programmer eliminates the need for a separate debugging tool. Arduino and Morpho connectors enables easy expansion with various shields and modules. Comprehensive software support includes STM32Cube software packages with examples and compatibility with popular IDEs like IAR, Keil, Mbed, and GCC- based options. Wide range of MCUs available with different MCU variants to suit various project requirements.



Fig 3: STM32 Nucleo Board

3.4 inch DSI Round Touch Display

A 3.4 inch DSI Round Touch Display is a circular display with a diameter of 3.4 inches that utilizes the Display Serial Interface (DSI) for communication. It's equipped with touch functionality, allowing users to interact with the display through gestures.

Features: Circular Shape, 3.4 Inch Diameter, DSI Interface, Touch Functionality.



Fig. 4: Round Display

CONCLUSION

This study tackles the difficulties of rapid spectral classification and mineral characterisation of the Moon's surface by utilizing the extensive dataset made available by the Chandrayaan-2 IIRS. The preprocessing step guarantees consistent data quality by concentrating on reducing geometry-based effects and choosing a well-covered lunar region for analysis. Finding unique mineralogical signatures in the hyperspectral data is made quick and easy with the use of AI/ML algorithms for spectral categorization. As a result, the geology and surface composition of the Moon can be better understood. The concept combines sophisticated data processing with intuitive visualization by displaying the final categorized data on a circular STM32 screen.

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Improving Marathi POS Tagging Accuracy by Addressing Linguistic Ambiguities and Exploring Effective Techniques

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ABSTRACT

Marathi, a morphologically rich and syntactically deep language, creates substantial challenges for parts of the speech (POS) identification such as lexical ambiguities, subtle inflexions, context dependencies, and semantic vagueness. Such traits often lead to mismatches in tracking and affect the efficacy of some downstream NLP tasks including but not limited to machine translation, emotional analysis, text summarization and information extraction. To solve these ambiguities, however, several disambiguation methods are needed that include linguistic-based rules, some probability identification such as the Hidden Markov model (HMM), some hybrid systems integrating statistical and rules based systems, knowledge-based technologies such as WordNet for disambiguation.

The study does point out the importance of resources such as Marathi WordNet, the annotated corpora of Indian Languages Corpora Initiative (ILCI) which are very essential to achieve optimal results in creating the tag algorithms. Yet, there are still issues like dialectal problems, under-resourced and understudied, poly-resource and morphological complexity. This paper opens up the debate about the concept of Part-of-Speech (POS) tagging in Marathi with particular reference to the ambiguities of identifying words and phrases or morphemes and inflectional patterns and syntactic structures of the language. We have used several approaches: From rules-based approaches to statistical approaches and hybrid methods to try and solve these problems, to fill the existing gaps in the solutions to give direction to further research.

KEYWORDS : POS, NLP, WordNet, Machine translation, Sentiment analysis, ILCI.

INTRODUCTION

One word that is often used in the area of Natural Language Processing (NLP) is POS tagging, which also known as part of speech is tagging, which has also been regarded as the basic unit of NLP but is essential to both information retrieval and machine translation (Rane et al, 2020; Singh et al, 2013). POS tagging is also defined as a tagging technique which identifies words in sequence and organizes them in grammatical patterns such as noun, verb or adjective, others and of course which is vital feature of NLP.

Marathi, a language predominantly spoken in Maharashtra, comes from the Indo-Aryan dialect group with over 83 million voices enrolled which makes it one of the major languages in computational linguistics systems. However, the growing focus on advancing the work continues to be slowed down

by the intricacies of Marathi due to its complex morphology and ambiguity. The ambiguities that naturally exist within languages present themselves as further challenges as one tries to understand the machine and thus even to a superficial tasks such as pos tagging or a word-level understanding like WSD (Dhopavkar et al 2015; Bagul et al 2014; Govilkar et al 2015).

In Marathi POS tagging, there are lexical, morphological, and contextual differences that contribute to the disambiguation which, as strong points of concern, may lead to errors in the applications utilizing the data at a later stage (Gaikwad et al., 2018). As a result of the shortage of consistent reliable annotated corpora and computing resources, Marathi has grown reliant on rule-based approaches that employ language specific guidelines in resolving images (Bagul et al., 2014; Govilkar et al., 2015).

TYPES OF AMBIGUITIES IN MARATHI POS TAGGING

Due to its complex morphology, free-ordering principle, and different meanings for the same word in different contexts, tagging the Parts of Speech becomes a challenging task with respect to Marathi language grammar. Lexical ambiguity, where in a given word may be used as or belong to more than one grammatical categories, for instance a noun or an adjective, structural ambiguity where the words in a sentence can be arranged in different ways leading to different meanings of that sentence and Phonological and pragmatic ambiguities all make the situation more complicated, especially when the actual texts are a discursive or other also informal type of text. These ambiguities must be solved through proper knowledge of Marathi language grammar rules along with contextual rules and therefore it becomes an important domain under NLP. Following section give the details about the typology of the Marathi POS ambiguities.

Lexical Ambiguity

A word is said to have lexical ambiguity when it can belong to more than one grammatical category. For instance, the term “laal,” depending on its usage, can take the position of either an adjective (Bagul et al., 2014: 34). It can also be an adverb more specifically the adverb of manner. This ambiguity is often resolved through contextual analysis.

Example: औषध घेतल्यावर थकवा जाणवतो

- Aushadh ghetyavar thakva jaanvato.
- Translation: “Fatigue is felt after taking the medicine.”
 - Ambiguity: The word थकवा (thakva) can function as:
 - Noun: Referring to “fatigue” in this context.
 - Verb: In other contexts, it could mean “to feel fatigued.”

Morphological Ambiguity

As Marathi has a rich morphology, a word can have more than one valid form which complicates tagging more. Nominalization or infinitive, verbs, necessitating disambiguation for example, the suffix -णे (Gaikwad et al., 2018)

Example: हा उपचार जड आहे

- Ha upchar jad aahe.
- Translation: “This treatment is intensive.”
 - Ambiguity: The word जड (jad) can be:
 - Adjective: Meaning as “intensive” or “serious,” in this context.

- Noun: Referring to a “weight” in other contexts.

Semantic Ambiguity

Contextual ambiguity is when a word is functionally dependent upon its syntactic placement. For example, according to its sentence construction, ते (te) can be a conjunction (and), (you) and pronoun (they) (Rane et al., 2020).

Example: रक्तदाब तपासण्यासाठी डॉक्टर सांगतात

- Raktadaab tapasnyasathi doctor sangtat.
- Translation: “Doctors recommend checking blood pressure.”
 - Ambiguity: The word रक्तदाब (raktadaab):
 - Verb: In the context of verb its meaning is “to press blood vessels,” though less common.
 - Noun: Here the correct meaning is “blood pressure”.

ROLE OF ANNOTATED CORPORA AND LEXICAL RESOURCES IN RESOLVING AMBIGUITIES

Marathi POS tagging require annotated corpora and lexical resources for removing ambiguity due to Marathi language complex morphology and syntax constraints. The Marathi WordNet and Indian Languages Corpora Initiative (ILCI) are two significant tools are very helpful in building accurate tagging systems (Kudale et al., 2022).

The ILCI corpus provides reliable dataset for the training and testing of POS taggers. This corpus encompasses a diverse collection of annotated phrases from different sectors, such as health, tourism, and agriculture. It has more than 100,000 annotated sentences (Rane et al., 2020). Due to the token level annotations of Marathi words both rule based and statistical tagging techniques get the information about contextual and lexical ambiguity. The ILCI corpus is an important resource for understanding different syntactic structures of words in a within a sentences, helps the researchers to refine tagging algorithms.

Marathi WordNet was developed at IIT Bombay (Dhopavkar et al., 2015), is another resource for understanding the lexical and semantic ambiguities in Marathi. It arranged words, as a semantic network, into collections of near synonyms, or synsets, and records lexical relations like hyponymy, antonyms, and hypernym. For example, the word पात्र (patra), meaning either “basin” or “eligibility,” can be disambiguated by looking at their synsets and the supporting evidence in context (Dhopavkar et al., 2015).

SURVEY OF EXISTING APPROACHES

The researchers have explored complex techniques, addressing the distinctive potential models and the challenges the language offers for Marathi Part-of-Speech (POS) tagging. The most popular Rule-based methods- an approach in which tags are assigned to a word and ambiguities resolved using manually created grammatical rules. This is especially effective because there aren't many Marathi language annotated corpora available. In recent years, hybrid systems which integrate rule-based procedures with statistical or machine-learning models have emerged, as an approach to enhance performance by leveraging both language knowledge and data-driven methods. This section describes the current approach, benefits, limitations, and working of the Marathi POS taggers.

Rule-Based Approaches

Rule-based methods remove ambiguity by applying predetermined linguistic rules. Rules based on contextual markers and suffixes have been created for Marathi. The rule that an adjective which comes after a noun is considered a modifier works well but in some situations it breaks down (Bagul et al., 2014).

Advantage: Simplicity and Interpretability.

Drawback: Demands large rule sets and struggles with invisible words (Bharati et al., 2006).

Manually created rules specific to Marathi grammar were used in both investigations. In order to properly tag segments of speech, these criteria addressed morphology and syntactic structures (Kulkarni & Sharma, 2023).

Advantage: Rule-based approaches are easy to apply and very interpretable. They are adept at capturing subtleties unique to a certain language.

Drawback: They are not scalable for huge datasets or unclear situations, need a lot of rule construction, and have trouble with invisible words.

Statistical Approaches

Probabilities are used to give tags in statistical models such as Conditional Random Fields (CRF) and Hidden Markov Models (HMM). For instance, an HMM-based POS tagger for Marathi was shown by Singh et al. (2013) to obtain 93.82% accuracy on a corpus related to tourism.

Advantage: Effectively manages huge datasets.

Drawback: Performance deteriorates in low-resource environments; requires large annotated corpus.

To address context-dependent tagging, researchers used deep

learning with attention mechanisms, a statistical technique that makes use of huge datasets. (Gupta & Deshpande, 2023).

Advantage: These statistical models are good at handling large datasets and adjusting to different linguistic patterns.

Drawback: Include significant computational costs and the need for huge annotated corpora, which reduces performance in low-resource scenarios.

Hybrid approaches

Hybrid approaches blend rule-based improvements with statistical methodologies. Through the resolution of defects from simply statistical models, these methods have demonstrated increased accuracy. For instance, ambiguity in adjectives and adverbs is decreased when grammatical rules are applied to accurate statistical predictions (Bagul et al., 2014).

Advantage: Strikes a balance between statistical robustness and rule interpretability.

Drawback: Requires a lot of computation.

This study suggested combining statistical models with linguistic rules to improve accuracy and overcome the drawbacks of strictly rule-based systems (Rane et al., 2020).

Advantage: The robustness of statistical models and rule interpretability are balanced by hybrid approaches. They improve outcomes by including grammatical and contextual features.

Drawback: The necessity to synchronize many methods makes the design computationally costly and difficult.

Knowledge-Based Disambiguation

Lexical resources like WordNet are used by knowledge-based systems to resolve ambiguity. Dhopavkar et al. (2015) achieved 92% accuracy in resolving lexical ambiguities in nouns and verbs using Marathi WordNet. By including ontological linkages, these systems improve comprehension of context.

Advantage: Requires less training data with annotations.

Drawback: Restricted by extensive lexical databases.

To resolve ambiguity in tagging nouns and verbs, we used lexical resources such as Marathi WordNet (Rane et al., 2020).

Advantage: Ontological linkages provide contextual clarity while reducing the requirement for massive annotated datasets.

Drawback: The extent and quality of Marathi lexical databases is limited.

Table 1 Summary of Literature Review

Study/Author(s)	Approach	Strengths	Limitations
Rane et al. (2020)	Manual annotation with linguistic rule-based analysis to address Marathi's complex morphology.	Identifies key linguistic challenges and proposes strategies for resource-scarce environments.	Limited scalability due to reliance on manual annotation; lacks advanced machine learning integration ACL Anthology
Kulkarni & Sharma (2023)	Handcrafted linguistic rules for morphological and syntactic analysis specific to Marathi.	Improved accuracy by leveraging Marathi-specific linguistic nuances.	Rule-based methods struggle with contextual ambiguities and scalability for large datasets ACL Anthology
Gupta & Deshpande (2023)	Deep learning using attention mechanisms to resolve context-dependent ambiguities.	Excels in handling complex contextual dependencies and ambiguous inputs.	Requires extensive labeled data for training; computationally expensive ACL Anthology
Bagul et al. (2014)	Rule-Based	Grammar rules effectively resolve ambiguity for known words. Demonstrates examples using suffixes and context.	Fails with unseen words. Requires exhaustive rule sets.
Singh et al. (2013)	Statistical (HMM-based)	Achieved 93.82% accuracy using tourism-domain corpus. Effective for probabilistic POS tagging.	Requires large annotated corpora. Limited generalizability across domains.
Rane et al. (2020)	Lexical and Functional POS Tagging	Discusses lexical (token-level) and functional (context-aware) approaches. Addresses ambiguous cases with examples from ILCI corpus.	Corpus-specific; lacks generalization to broader datasets.
Dhopavkar et al. (2015)	Knowledge-Based (WordNet for WSD)	Resolves lexical ambiguity using Marathi WordNet. Achieved 92% accuracy for word-level disambiguation.	Focused only on word-level ambiguity; no structural ambiguity handling.

Gaikwad et al. (2018)	Rule-Based	Integrates Marathi grammar rules for POS tagging. Highlights morphological complexity and solutions via standard POS tags.	Lacks scalability to large, diverse datasets.
Bharati et al. (2006)	Annotating Guidelines for Indian Languages	Standardized tag sets for Indian languages, ensuring consistency across multiple languages.	Primarily focused on Hindi; adaptations for Marathi may require further refinement.
Ekbal & Bandyopadhyay (2007)	HMM for Indian Languages	Addresses tagging challenges in multiple Indian languages, achieving 82.05% accuracy for Hindi.	Suffix-based handling of unknown words is limited in complexity.
Vaswani et al. (2004)	Hybrid Model for Hindi	Demonstrated the benefits of combining statistical methods with grammar-based corrections for improved tagging accuracy.	Developed for Hindi; direct application to Marathi may require additional linguistic adaptations.

CONCLUSION

Resolving ambiguities in Marathi POS tagging is crucial to building a robust and reliable system. NLP applications include sentiment analysis and information retrieval, as well as machine translation. There are many different syntactic constructions and a rich morphology in Marathi intrinsic ambiguities that make automated systems difficult to use such as lexical structural and context-based ones processing very challenging. Existing methodologies have particularly rule-based and hybrid approaches demonstrated promise in resolving these doubts. Annotated corpora are scarce though variety of dialects and the absence of sophisticated computational models specifically designed for Marathi often restrict their effectiveness.

FUTURE DIRECTIONS

POS tagging in Marathi requires deliberate effort in order to improve system performance and overcome existing constraints. Annotated resources, such as diverse datasets covering different dialects and domains, are essential to ensuring inclusive and reliable language processing. The accuracy of advanced models, including transformer-based designs such as BERT, can be greatly enhanced by applying Marathi-specific fine-tuning approaches.

It is useful to have knowledge of cross-lingual approaches from similar Indian languages, such as Bengali and Hindi, which can be modified in order to fit the morphological structure of the Marathi language.

Furthermore, one innovative method for improving tagging accuracy dynamically involves the combination of interactive disambiguation systems that take into account real-time feedback from users. All of these methods together elevate Marathi POS tagging to new levels of effectiveness and utility.

- 1) Annotated Resources Expansion: Developing different datasets that cover multiple dialects and domains is one way to expand annotated resources.
- 2) Advanced Models: Making Use of Advanced Models BERT and other transformer based models are being trained for Marathi.
- 3) Cross-Lingual Understanding: Modifying answers from languages with diverse morphologies.
- 4) Interactive Disambiguation: Developing systems that leverage user input to improve tagging is known as interactive disambiguation.
- 5) Resource Expansion: Create annotated corpora that span several dialects and domains.
- 6) Advanced Models: These Uses fine-tuning techniques to train transformer-based models such as BERT for Marathi.
- 7) Interactive Systems: For real-time ambiguity resolution, integrate user input into tagging processes.

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A Review of Personalized Haircare Product Recommendation System Using Ingredient-Based Analysis and Machine Learning

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ABSTRACT

The Haircare Recommendation System is an innovative solution designed to provide personalized haircare product recommendations based on ingredient analysis and individual hair concerns. By leveraging machine learning techniques, including Processing (NLP) and Natural Language recommendation algorithms, the system compares user data—collected via a survey—with a curated and expert-verified dataset of haircare products. The system then suggests suitable products or specific ingredients that are most beneficial for a user's unique hair type or problems, such as dryness, dandruff, or hair loss. Through this approach, the system simplifies the often-overwhelming process of choosing haircare products by decoding complex ingredient lists and offering science-backed recommendations tailored to each user. This technology not only empowers consumers to make informed product choices but also improves overall hair health by guiding them toward products with proven benefits for their specific needs. The system has the potential to evolve into a comprehensive tool that integrates user feedback, real-time product updates, and ingredient interaction analysis, ensuring continuous improvement and personalization of recommendations.

KEYWORDS : *Haircare, Ingredient-based machine learning, Recommendation, Natural language processing (NLP), Cosine similarity, Collaborative filtering, Personalized care, Recommendation system, Hair types, Ingredient analysis.*

INTRODUCTION

The haircare industry boasts an extensive array of products designed to address various issues, such as oiliness, frizz, dandruff, and hair thinning. However, despite the abundance of options, consumers often struggle to identify the right products suited to their unique needs. This challenge arises primarily due to the complex and technical ingredient lists on product labels, which many users find difficult to interpret. As a result, they frequently resort to costly and potentially harmful trial-and-error methods, further exacerbating their haircare concerns instead of resolving them. The lack of personalized guidance in navigating the vast landscape of haircare products adds to this dilemma, leaving consumers without the necessary tools to make informed decisions.

Haircare requirements are inherently individualized, influenced by diverse factors such as hair texture, scalp

condition, environmental factors, and lifestyle choices. A one-size-fits-all approach to haircare is rarely effective, as it fails to accommodate the specific and often intricate needs of different individuals. This highlights the critical need for solutions that go beyond generic recommendations, offering personalized insights that align closely with a user's unique hair concerns and preferences.

To address these challenges, the Haircare Recommendation System harnesses the power of machine learning to deliver tailored product recommendations. By analyzing ingredient lists and matching them with user-specific inputs, the system bridges the gap between technical product data and consumer understanding. Using Natural Language Processing (NLP) for ingredient interpretation and machine learning algorithms for personalized suggestions, the system processes data collected via Google Form surveys and compares it against

a meticulously curated dataset of haircare products. This ensures that users receive recommendations that are not only scientifically grounded but also highly relevant to their individual needs.

Through this innovative approach, the Haircare Recommendation System simplifies the often-overwhelming process of product selection. By enhancing clarity and reducing uncertainty, it empowers users to make confident and informed choices. Ultimately, this system promotes better long-term hair health by guiding consumers toward products with proven efficacy, transforming the way users approach their haircare routines in an increasingly complex market.

Motivation

Haircare is a crucial aspect of personal grooming, yet finding the right products to address specific issues like dryness, dandruff, hair thinning, and split ends remains a challenge for many consumers. Each problem requires distinct ingredients, but the lack of knowledge to interpret ingredient lists often leaves users dependent on marketing claims rather than scientific evidence, resulting in the use of ineffective or harmful products. As awareness of personalized skincare and healthcare grows, there is a rising demand for similar personalized solutions in hair care. This project is motivated by the need for a system that guides users in selecting products based on scientific analysis of ingredients rather than brand-driven claims. Hair types and concerns vary widely, with no single product universally effective—curly, dry hair benefits from moisturizing formulations, while fine, oily hair requires lightweight alternatives. Given this diversity, a personalized, data-driven haircare recommendation system is essential to help consumers make informed decisions, reduce trial-and-error costs, and promote better hair health through accurate, tailored solutions.

Objectives

- To Provide tailored haircare suggestions by analyzing product ingredients and matching them to users' specific hair types and concerns.
- To Use advanced machine learning models to deliver accurate, data-driven recommendations, reducing ineffective product usage.
- To Ensure the system can expand with more data, user feedback, and real-time updates for continuous improvement.
- To analyze and mitigate biases in the recommendation process by incorporating diverse datasets and ensuring fairness across various hair types, concerns, and demographics.

Applications

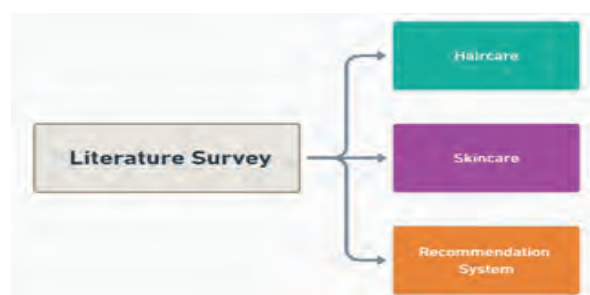
- Tailors product suggestions based on users' hair types and concerns by analyzing product ingredients
- Educates users on the benefits and risks of ingredients, enabling informed product choices
- Supports haircare professionals with tailored recommendations and integrates with e-commerce platforms for personalized online shopping.
- Provides haircare market trends and insights by analyzing user preferences and product data for businesses.
- Customizes Haircare Routines based on individual user profiles, including hair type, concerns, and goals, to create personalized daily, weekly, and monthly haircare schedules.
- Tracks Hair Health Progress by logging product usage and monitoring changes in hair condition, offering users actionable insights for improving their haircare regimen.
- Identifies Ingredient Sensitivities by alerting users to potential allergens or harmful ingredients based on their personal sensitivities and preferences.

LITERATURE SURVEY

The literature survey comprises of three categories as shown in Fig.2.

Proposal of Recommender System Based on User Evaluation and Cosmetic Ingredients (Hirotoishi Honma et al.) paper introduces a recommendation system based on user evaluations and ingredient data. It is particularly accurate in recommending products for specific skin types. However, the system may not generalize well across different regions due to varying cosmetic preferences [1].

Cosmetic Product Selection Using Machine Learning (Rubasri S et al.) paper applies machine learning and natural language processing (NLP) techniques to analyze cosmetic products and user preferences. It reports high accuracy rates (85-93%) but notes a decline in accuracy with new or unknown ingredients [2]. Refer Table 1.



A Content-Based Skincare Product Recommendation System (Gyeongun Lee et al.) paper focuses on content-based filtering to match skincare products with user profiles, such as skin type and product type. The system provides personalized recommendations based on ingredients but is limited to ingredient-based filtering and may not account for large product variations [3]. Refer Table 1.

Recommender System Based on User Evaluations and Cosmetic Ingredients (Yoko Nakajima et al.) authors propose a system combining user reviews and product ingredients to recommend skincare products. The system uses an Ingredient Frequency - Inverse Product Frequency (IF-IPF) method to rank ingredients. However, it heavily relies on user reviews, which may be biased or incomplete [4]. Refer Table 1.

AI in Recommender Systems (Qian Zhang et al.) paper reviews AI methods such as deep learning, fuzzy logic, and transfer learning applied in recommendation systems. It highlights how these techniques improve personalized recommendations but notes challenges in implementing complex models for smaller datasets [5].

Recommender Systems Leveraging Multimedia Content (Yashar Deldjoo et al.) paper discusses the use of multimedia content, such as images, to improve recommendation systems. While useful for categorizing products, it is limited to visual identification and does not directly address ingredient-based recommendations [5].

Wide & Deep Learning for Recommender Systems (Heng-Tze Cheng et al.) paper proposes a method combining linear models and deep neural networks to improve recommendation accuracy with sparse data. The model performs well but may over-generalize in cases with limited user interaction [5].

Design and Implementation of Hair Recommendation System Based on Face Recognition (Zhuocheng Liu et al.) paper discusses using facial recognition algorithms to recommend hairstyles by analyzing facial features. Deep learning models, such as Convolutional Neural Networks (CNN), are employed. The system provides personalized recommendations to enhance user satisfaction. However, it is limited by not accounting for hair texture or type, which could affect recommendation accuracy [6].

Image-Based Hair Segmentation Algorithm for Automatic Facial Caricature Synthesis (Shen et al.) paper presents an algorithm for hair segmentation using graph cuts optimization and K-means clustering. The algorithm achieves 90% hair detection accuracy and fast processing. Although the paper is focused on caricature synthesis, its hair segmentation techniques could be adapted for haircare product recommendations by analyzing hair texture and volume [6].

Cosmetic Product Recognition via Machine Learning (Saiyed Umer et al.) paper utilizes machine learning classifiers like logistic regression and support vector machines to recognize cosmetic products. Though primarily focused on image-based recognition, the approach could be adapted for ingredient-based skincare recommendations [7].

Personalized Recommendation via Prompting Large Language Models (Hanja Lyu et al.) paper uses large language models (LLMs) with prompting strategies to enhance recommendation systems. LLMs outperform traditional methods, especially with sparse data, but may struggle with vague or inconsistent user inputs [7].

A Skincare Recommender System Using Collaborative Filtering and NLP (Hsiao-Hui Li et al.) paper combines collaborative filtering with NLP techniques to improve skincare product recommendations. The system excels at matching users with suitable products based on reviews and purchase history but may face challenges with first-time users due to the cold-start problem [8].

Knowledge-Based Skincare Product Recommendation (Gyeongun Lee et al.) is knowledge-based system uses content-based filtering to recommend products by analyzing ingredients. It focuses on compatibility with skin or hair types. However, regular updates are required to keep the system relevant as new products emerge [8].

Study on Hair Fall with Hair-Related Problems among Males of Age 18-50 Years (Mahendra Varman et al.) is a cross-sectional community study conducted on 393 males aged 18-50 using interviews and questionnaires. The study reveals a 60.3% prevalence of hair fall, with correlations to lifestyle and depression. Although limited to males in Chennai, it provides insights into common hair-related issues that could inform haircare recommendations [9].

Figaro-tresses: A Dataset for Evaluating Hair Assembly Features Before and After Cosmetic Treatment (Mattia Savardi et al.) research analyzes hair assembly features before and after cosmetic treatments by photographing hair tresses treated with shampoo and conditioner. The study focuses on hair tresses of virgin and bleached hair types, offering insights into how different hair types react to treatments. However, it is limited to fine Caucasian hair, excluding other hair textures and types [10].

Review-Driven Beauty Product Recommendation System (S. Niharika et al.) Sentiment analysis and K means clustering are used to analyze user reviews and product features. While the system successfully recommends skincare products based on skin type and issues, it heavily depends on user reviews from specific platforms, which may limit its application [11].

Natural Language Processing (NLP) in Recommendation Systems (Ondongo Aucibi et al.) uses NLP techniques like sentiment analysis and deep learning models significantly improves the accuracy of personalized recommendations. However, high computational requirements and difficulties with sparse data are noted as challenges [12].

Hair Cosmetics: An Overview (Maria Fernanda Reis) review article explores the formulations, safety, and modes of action of various hair cosmetics like shampoos, conditioners, and dyes. The paper emphasizes the importance of haircare products in alopecia treatments but lacks data on specific ethnicities, particularly Hispanic hair types [13].

Table. 1. Accuracy Comparison of Cosmetic Recommender Systems

Title	Accuracy
Recommender System Based on User Evaluations and Cosmetic Ingredients	~80%, Non-recommended: ~60%
Proposal of Recommender System Based on User Evaluation and Cosmetic Ingredients	Invalid (<5% for all attributes)
A Content-based Skincare Product Recommendation System	16% to 17%
Cosmetic Product Selection Using Machine Learning	64.37% to 82.59%
The Prediction of Hairfall Pattern in a Person Using Artificial Intelligence for Better Care and Treatment	93% (internal data), 85% (external data)

Various Studies on Hair Loss and Contributing Factors (Khokhar et al., Poonia et al., Bkry et al., Nayak et al., Alomaish et al.) is a compilation of various studies on hair loss and its contributing factors such as vitamin deficiencies, stress, lifestyle, and quarantine effects. Different methodologies were used, such as questionnaires, serum tests, and clinical studies. The limitations of these studies include small sample sizes and region-specific findings, with little focus on ingredient-based recommendations [14].

The Prediction of Hairfall Pattern Using AI for Better Care and Treatment (Farooq et al.) paper uses AI algorithms such as SVM, KNN, and Random Forest to predict hairfall patterns using data from Kaggle. The study highlights the importance of features like lifestyle factors in predicting hair loss. Despite its low accuracy (16-17%), it suggests potential applications for improving personalized haircare recommendations [14]. Refer Table 1.

CHALLENGES

- High Computational Demand:** AI-driven recommendation systems require significant resources, making real-time scalability a challenge.
- Data Dependency and Bias:** Heavy reliance on user feedback can introduce biases and result in incomplete datasets, affecting recommendation accuracy.
- Cross-Domain Adaptability:** Models often face difficulties in generalizing across different product categories or regions with varying preferences.
- Data Privacy and Security:** Ensuring that user data, particularly personal and sensitive information related to haircare preferences, is kept secure and compliant with privacy regulations like GDPR.
- Ingredient Complexity:** Understanding and analyzing the vast variety of ingredients in products to provide accurate and effective recommendations while considering their interactions and potential effects on different hair types.
- User Education and Trust:** Educating users about the science behind ingredient analysis and building trust in the recommendation system, especially when new or unfamiliar ingredients are involved.

CONCLUSION

The Haircare Recommendation System addresses the longstanding challenge of selecting effective haircare products by utilizing state-of-the-art machine learning algorithms, including content-based filtering, collaborative filtering, and Natural Language Processing (NLP). This combination enables the system to decode complex ingredient lists and align them with individual users' hair types and concerns. By offering personalized, science-backed recommendations, the system empowers users to make informed choices, eliminating the confusion often associated with navigating a saturated and overwhelming haircare market.

A significant advantage of this system lies in its ability to enhance user satisfaction by minimizing trial-and-error methods and promoting better hair health. Instead of relying on marketing claims or anecdotal evidence, users receive tailored recommendations grounded in rigorous ingredient analysis and data-driven insights. This approach not only helps users avoid ineffective or potentially harmful products but also encourages long-term, sustainable haircare practices. The result is a user-centric solution that fosters trust and confidence in the recommendation process.

Looking forward, the Haircare Recommendation System holds immense potential for growth and adaptability. Expanding its dataset to include a wider variety of hair types, regional

preferences, and newly introduced products will make the system even more inclusive and effective. Additionally, integrating real-time updates, advanced ingredient interaction analysis, and user feedback loops will enhance its accuracy and relevance. The system can also be extended into mobile apps and e-commerce platforms, providing personalized shopping experiences, and supporting haircare professionals with advanced tools for client recommendations.

In summary, the Haircare Recommendation System exemplifies the transformative impact of technology and innovation in the beauty industry. By bridging the gap between scientific knowledge and consumer needs, it offers a highly relevant and accessible solution to personalized haircare. As the system evolves and adapts, it is poised to not only empower individual users but also drive the industry toward more effective, tailored, and sustainable approaches to haircare. This makes it a valuable tool for consumers, professionals, and businesses alike, ensuring its significance and impact in the growing field of personalized beauty solutions.

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PYNQ Framework based Defect Detection Using Convolutional Neural Networks

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ABSTRACT

This review focuses on the integration of Field-Programmable Gate Arrays (FPGAs) with Convolutional Neural Networks (CNNs) to improve real-time defect detection in product quality control. Traditional manual inspection methods are often inefficient, slow, and prone to errors, which limits their effectiveness in modern manufacturing environments. By utilizing FPGAs for parallel processing, the proposed system aims to deliver high-speed and accurate defect detection, outperforming conventional methods.

Aligned with the principles of Industry 4.0, this approach promotes the use of advanced technologies to automate and optimize manufacturing processes. The review also addresses challenges in deploying AI models on FPGA hardware, including optimization techniques and trade-offs between accuracy and computational efficiency. Overall, the project demonstrates how such innovations can enhance manufacturing quality control, reduce defect rates, and support the shift towards smarter, more efficient production systems.

KEYWORDS : *FPGA, CNN, Defect detection, Industry 4.0. Real time processing.*

INTRODUCTION

The manufacturing sector is undergoing significant transformation due to the integration of cutting-edge technologies such as Artificial Intelligence (AI) and machine learning. These advancements are reshaping the industry by enhancing automation, improving efficiency, and optimizing production processes. One of the critical challenges in modern manufacturing is ensuring consistent product quality. Traditionally, quality control has depended on manual inspections, which are time-consuming and susceptible to human errors, and insufficient for handling the high-speed demands of contemporary production lines. Automated systems have emerged as an alternative, but they too often fall short in terms of accuracy and real-time performance, especially when dealing with complex defect detection tasks.

This review explores the use of Field-Programmable Gate Arrays (FPGAs) in combination with Convolutional Neural

Networks (CNNs) to address these limitations. FPGAs are well-suited for tasks that require parallel processing, making them ideal for handling the intensive computations involved in CNN-based image recognition. CNNs, on the other hand, are highly effective at identifying and classifying defects in images, making them a powerful tool for automated quality control. This paper examines the challenges and benefits of implementing such a system, highlighting its alignment with Industry 4.0 goals that focus on smart, automated, and efficient manufacturing processes. Through this review, we assess the potential of FPGA-based CNNs to significantly enhance the speed, accuracy, and overall efficiency of quality control in modern manufacturing environments.

Block Diagram

The workflow begins with the product coming directly from the manufacturing operation, ready for quality inspection. A camera captures an image of the product, providing the main

data needed for detecting defects. This image then undergoes a series of preprocessing steps, such as noise reduction, contrast adjustment, and resizing, to prepare it for further analysis. Preprocessing is essential to ensure that the image is in optimal condition and enhances the accuracy of the defect detection process.

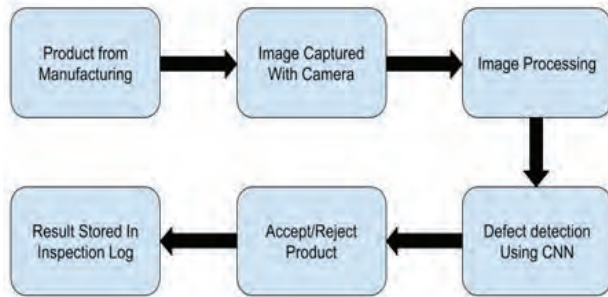


Fig. 1: Block Diagram

Once preprocessing is complete, the image is passed to a custom convolutional neural network (CNN) that has been trained to detect defects in products. The CNN examines the image, looking for any irregularities or deviations from the standard that would indicate a defect. Based on the analysis, the system makes an automated decision to either accept or reject the product. Accepted products meet the quality standards, while those with detected defects are rejected. Finally, the result of each inspection, whether accepted or rejected, is logged into an inspection log. This log is valuable for tracking inspection outcomes over time, allowing the manufacturer to monitor defect rates and assess the overall quality of production. The entire workflow provides an automated, efficient solution for integrating image-based defect detection into the manufacturing process, improving consistency and reducing human error in quality control.

LITERATURE SURVEY

[1] This study presents an AI-based approach to enhance visual inspection in manufacturing, using a custom Convolutional Neural Network (CNN) to find defects in casting products. The model achieved a 99.86% accuracy, significantly improving over traditional manual methods which typically reach only 80% accuracy. By integrating deep learning into a shop-floor application, the inspection process becomes automated, reducing human errors and inefficiencies. The paper highlights the use of a real-world dataset of casting products, emphasizing the practical implementation of the method for smart manufacturing environments. The approach is particularly useful for real-time, high-accuracy inspection, which is critical for achieving 100% inspection goals in advanced manufacturing systems. [2023]

[2] This research focuses on Deploying a lightweight convolutional autoencoder (CAE) on an FPGA for detecting anomalies in vibration-based condition monitoring. The model is designed to be efficient for edge computing, achieving an accuracy of 88.8 percent on a CPU and 85.02 percent on an FPGA with a significant speed-up in inference time. It effectively identifies anomalies in vibration data from helicopter accelerometers by transforming 1-D time-series data into images using various encoding methods, with scalograms providing the best results. This approach offers a practical solution for real-time, on-site machine health monitoring. [2022]

[3] This research presents an FPGA implementation the system on FPGA, the deep convolutional neural network (DCNN) is utilized to analyze chest X-ray images for the detection of tuberculosis and pneumonia. The proposed lightweight DCNN model, trained on Google Cloud CPU, achieved high accuracy values of 96.39 percent and 95.63 percent on the CPU and PYNQ-Z2 FPGA, respectively. The FPGA-based implementation significantly reduces inference time by 85.19 percent compared to the CPU-based implementation. This study demonstrates the potential of FPGA based DCNN models for efficient, real-time medical image analysis in resource-constrained environments. [2022]

METHODOLOGY

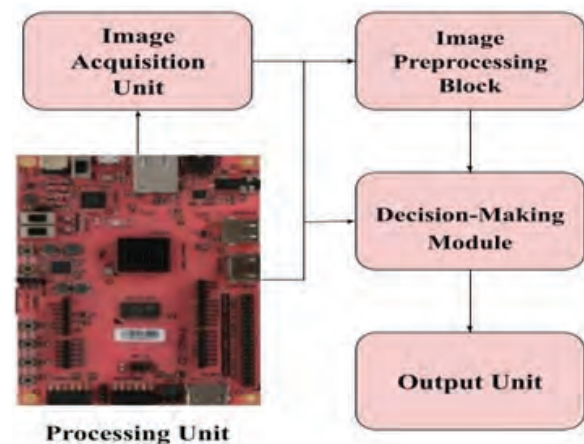


Fig. 2: System Architecture

Image Acquisition Unit

Camera: A high-resolution camera captures product images directly from the manufacturing line. These images serve as the primary input for defect detection and are transmitted to the FPGA for processing.

Interface: The camera is connected to the PYNQ-Z2 FPGA board via the available input ports (HDMI or USB).

Image Preprocessing Block

Image Preprocessing: Once the image is captured, preprocessing is applied to improve quality, reduce noise, and prepare the image for analysis. Techniques such as resizing, rotation, and scaling are performed as needed to make the input compatible with the CNN

FPGA Unit (Processing Block)

FPGA (PYNQ-Z2 Board): The heart of the system is the FPGA, particularly the PYNQ-Z2 board, which features a Xilinx Zynq-7000 SoC combining ARM processors and FPGA fabric. This hardware handles parallel processing of image data to achieve real-time performance.

CNN Implementation: A trained Convolutional Neural Network (CNN) model is deployed on the FPGA. The CNN is optimized to run on the FPGA's programmable logic for fast, efficient defect detection. The model is responsible for feature extraction and defect classification using convolutional and pooling layers.

Decision-Making Module

Defect Classification: The CNN processes the preprocessed images and classifies them as either defect-free or defective.

Thresholding Logic: Based on the CNN's output, an accept/reject decision is made using predefined thresholds to ensure that only defect-free products pass through.

Accept/Reject Decision: The system flags products accordingly, generating a signal for either acceptance or rejection.

Output Unit

Control Signal: For rejected products, the system sends a control signal to the manufacturing line to remove defective items from production. This signal is managed by the FPGA for real-time responsiveness.

Inspection Log: Each result (accept or reject) is recorded in an inspection log, which serves as a reference for tracking product quality over time.

SYSTEM ARCHITECTURE

CNN

A Convolutional Neural Network (CNN) is a specialized type of deep learning architecture widely utilized in the field of computer vision. Computer vision, a branch of artificial intelligence, enables machines to analyze, interpret, and derive meaningful insights from visual data such as images and videos.

In the machine learning, artificial neural networks have

demonstrated exceptional performance across various data types, including images, audio, and text. Different neural network architectures are designed for specific tasks—for instance, Recurrent Neural Networks (RNNs) are effective for sequence prediction tasks, while Convolutional Neural Networks (CNNs) are particularly suited for image classification.

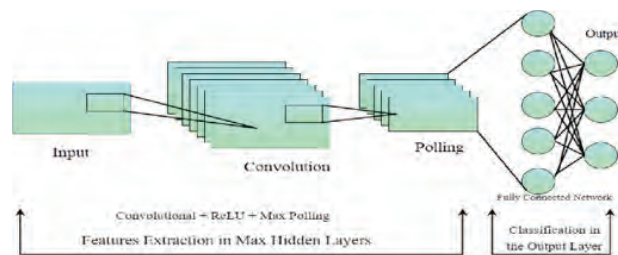


Fig. 3. CNN architecture

A Convolutional Neural Network (CNN) is a type of deep learning architecture specifically designed for processing and analyzing visual data, often used in tasks such as image classification and recognition. The general architecture includes:

Convolutional Layers: These layers apply filters to the input image, extracting low-level features such as edges, textures, and patterns.

Pooling Layers: Pooling reduces the spatial dimensions of the feature maps, which reduces computation and helps the CNN focus on the most critical parts of the image.

Fully Connected Layers: Once the features are extracted, the fully connected layers take over to make the final classification decision, identifying whether the product is defective or not.

Model Selection

A lightweight CNN architecture, such as MobileNet or Tiny-YOLO, can be utilized due to their balance of accuracy and efficiency when deployed on edge devices like FPGAs. These models are highly suitable for real-time processing on the PYNQ-Z2 board due to their lower computational requirements compared to larger models like ResNet.

The CNN model is first trained on a broad image dataset and later refined using a specific dataset that includes product defects, ensuring that it can accurately identify the types of defects relevant to the manufacturing line. CNNs are ideal for project because they automatically learn to detect product defects from images, ensuring high accuracy. They are fast, suitable for real-time detection, and can adapt to different types of defects. When combined with the PYNQ-Z2 board, CNNs run efficiently using FPGA's parallel processing, making them perfect for your embedded system.

PYNQ Z2

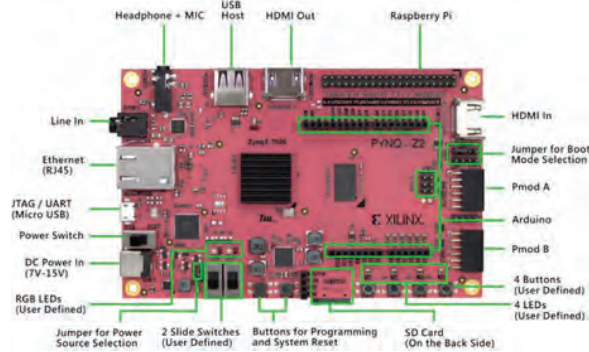


Fig. 4. PYNQ Z2 board

The PYNQ-Z2 board is built on the Xilinx Zynq-7000 SoC, which combines an ARM Cortex-A9 processor with FPGA fabric. This hybrid architecture enables both software and hardware processing, providing a balance of performance and flexibility for the proposed system. The ARM processor manages general control functions, while the FPGA fabric accelerates computationally intensive tasks, such as running convolutional neural networks (CNNs).

Key Features of the PYNQ-Z2 board

1. Two core ARM CortexA9 processor which runs at the 650 MHz.
2. Programmable Logic (PL): The FPGA fabric enables parallel processing of image data, speeding up computation.
3. DDR3 memory of 512 MB, providing adequate storage for intermediate image data and CNN weights.
4. High-speed input/output: The PYNQ-Z2 board supports HDMI, USB, and GPIO interfaces, which allow for seamless connectivity with the camera and control systems in the manufacturing line.

Optimization of CNN on FPGA

The CNN model deployed on the PYNQ-Z2 board is optimized for real-time defect detection. To ensure high efficiency, several techniques are employed:

Model Quantization: Quantizing the CNN to reduce the precision of weights and activations can significantly reduce the FPGA's resource usage and improve processing speed without sacrificing much accuracy.

Pruning: This involves removing less important parameters from the CNN to reduce computation, resulting in a more lightweight model that is faster to run on the FPGA.

Layer-wise Parallelism: The CNN leverages the FPGA's parallel processing capabilities by distributing computations across convolutional and pooling layers, improving the speed of operations.

CONCLUSION

Enhanced Efficiency and Accuracy: The integration of FPGA technology with CNNs significantly improves the speed and accuracy of defect detection in manufacturing. This system's ability to process high-resolution images in real-time addresses the limitations of traditional manual inspections and existing automated systems, offering a more reliable solution for ensuring consistent product quality.

Alignment with Industry 4.0 Goals: The proposed FPGA-based CNN system supports the principles of Industry 4.0 by fostering smarter, automated, and more efficient manufacturing processes. By enhancing real-time performance and scalability, this approach demonstrates the potential to revolutionize quality control in modern manufacturing environments, paving the way for more advanced, data-driven production lines.

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Deep Learning for Driver Drowsiness Detection: A Comprehensive Review

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ABSTRACT

Driver drowsiness is a significant factor contributing to road accidents and fatalities worldwide, prompting the need for reliable detection systems to enhance road safety. This comprehensive review explores advancements in deep learning techniques for driver drowsiness detection, evaluating the efficacy of various approaches, including behavioural, physiological, and vehicular measures. Behavioural methods utilize cameras to monitor physical signs, such as eye movement and head position, while physiological techniques employ bio-sensors to capture EEG, EOG, and ECG signals indicative of fatigue. Vehicular data, including steering patterns and lane deviations, offers additional insights into driver alertness. The review highlights the potential of deep learning, particularly convolutional neural networks (CNNs) and hybrid models, in analyzing complex data, improving feature extraction, and achieving high accuracy. However, challenges such as real-time processing, dataset diversity, and sensitivity to environmental factors remain. This study underscores the importance of multimodal systems that combine multiple data sources for robust and accurate drowsiness detection, contributing to the development of enhanced driver monitoring technologies aimed at reducing accidents due to fatigue.

KEYWORDS : *Driver drowsiness detection, Deep learning, Behavioural measures, Physiological measures, Vehicular measures, Hybrid approaches, Feature extraction, Real-time performance, Road safety, Fatigue detection.*

INTRODUCTION

Driver drowsiness is a major contributor to road-related accidents, posing significant risks to public safety and resulting in severe economic and societal losses. It arises from factors such as fatigue, sleep deprivation, and lowered sensory functions, which impair cognitive abilities, reaction times, and decision-making. Early detection of drowsiness is critical to mitigating accidents, and various methods as depicted in Figure 1, have been developed to address this issue, including subjective reporting, biological monitoring, physical behavior analysis, vehicular behavior tracking, and hybrid approaches that combine these techniques [1]. Detecting drowsiness in its early stages is particularly vital, with features such as facial expressions, biological indicators, and vehicle behavior providing essential data for timely intervention [2]. Eye activity measures, such as PERCLOS

and blink frequency, have been identified as effective early indicators of drowsiness, offering the potential to warn drivers before their fatigue leads to accidents; however, these measures face challenges in scalability and robustness in real-world environments [3]. Efforts to enhance fatigue detection systems focus on data acquisition, feature extraction, and fatigue assessment, but significant challenges persist, including late detection, intrusiveness, and the diversity of driver profiles [4,5].

Physiological monitoring methods like EEG, while accurate, are intrusive, and behavioral monitoring systems, although less invasive, are affected by external factors such as lighting and privacy concerns. The lack of standardized on-road data collection protocols and subjective inconsistencies in drowsiness labelling further hinder the reliability of current detection systems, highlighting the need for innovative,

scalable, and robust solutions to advance real-world applicability.

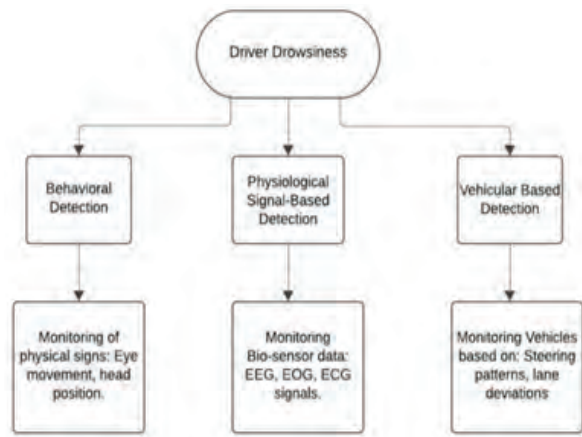


Fig. 1. Drowsiness Detection Methods

Behavioral Detection

Behavioral measures, known for their non-intrusive nature, analyze physical cues like eye movements, facial expressions, and head posture to detect drowsiness. Multichannel models such as multichannel CNN-GRU capture multi-scale features and temporal dependencies [6]. Advanced approaches like 2s-STGCN analyze spatial-temporal relationships in video data, achieving high accuracy on datasets like YawDD and NTHU-DDD [7]. Hybrid architectures further enhance accuracy, with a 30-layer CNN combined with HOG and PCA achieving 99.6% accuracy on YawDD [8]. Multi-granularity models like RF-DCM adaptively improve detection by focusing on global and local facial regions [9]. Real-time detection systems such as MCNN, optimized using the Flamingo Search Algorithm (FSA), classify drowsiness using datasets like YawDD and NTHU-DDD [10]. Lightweight CNN-based systems like DriCare effectively monitor facial features, achieving 93.6% accuracy in real-world scenarios [11]. Video-based models like VBFLFA, integrating temporal and spatial features, achieve 98.93% accuracy on YawDD [12]. Innovations also include real-time facial expression analysis [13], transfer learning for eye movement behavior [14], and lightweight CNN-based eye status monitoring [15]. Edge-optimized models ensure efficient eye blink detection with minimal resources [16]. Datasets like FatigueView provide multi-camera data with hierarchical annotations, enhancing real-world detection research [17].

Physiological Signal-Based Detection

Physiological signals such as EEG, ECG, and EOG offer promising avenues for drowsiness detection. Deep neural networks classify drowsiness from these signals [18], while

methods addressing eye blink artifacts improve EEG-based detection [19]. Combining EEG with visual cues enhances detection comprehensiveness [20]. Attention-guided multiscale CNNs capture detailed features for fatigue detection [21], while non-invasive techniques like fNIRS measure brain activity through blood oxygenation changes, offering further potential [22].

Vehicular Based Detection

Vehicular-based approaches use multimodal data such as environmental sensors and driving metrics (e.g., lane departures, steering patterns) to predict drowsiness. These methods, non-invasive and scalable, achieved a 64.6% unweighted recall, with scope for improvement using larger datasets [23]. Such measures are often integrated with physiological data to create comprehensive detection systems [24].

Advancements in Driver Drowsiness Detection Techniques

Recent advancements include optimizing CNN architectures using Genetic Algorithms to enhance performance [25] and federated transfer learning to train models without sharing raw data, safeguarding privacy [26]. Hybrid machine learning techniques enable early drowsiness detection [27], while GANs address dataset biases, ensuring fairness across demographics [28]. Real-time algorithms personalize fatigue detection for individual drivers [29], and Multi-Channel SOBI methods analyze EEG signals, improving sensitivity and reliability [30].

Goals and Motivation

The primary goal of driver drowsiness detection systems is to enhance road safety by providing timely alerts to prevent accidents caused by fatigue-related impairment. Traditional methods, while effective in controlled environments, often fail to deliver consistent accuracy and reliability in real-world conditions. The rapid advancements in machine learning and deep learning technologies have opened new possibilities for creating robust, non-intrusive, and real-time detection systems. Motivated by the pressing need to reduce road fatalities, researchers aim to develop solutions that integrate behavioral and physiological indicators to improve detection precision. Furthermore, addressing challenges such as bias in detection models, scalability, and individual variations in drowsiness patterns is critical to making these systems practical and widely applicable. By leveraging innovative approaches such as multimodal data fusion, privacy-preserving methodologies, and adaptive algorithms, the field seeks to create personalized, efficient, and accessible systems that cater to diverse driving environments and populations.

Objectives

1. To analyze and evaluate recent advancements in driver drowsiness detection systems, focusing on their methodologies, accuracy, and real-world applicability.
2. To identify limitations in current detection approaches and propose strategies to address challenges such as bias, scalability, and integration of multimodal data.
3. To highlight future research directions aimed at developing efficient, non-intrusive, and personalized systems that cater to diverse driving conditions and populations.

Major Contributions of the Article

This article provides a comprehensive review of advancements in driver drowsiness detection systems, emphasizing the integration of machine learning and deep learning techniques to enhance detection accuracy and scalability. It categorizes detection approaches into behavioral, physiological, and hybrid methods, critically analyzing their strengths, limitations, and applicability to real-world scenarios. Additionally, the article highlights innovative solutions such as multimodal data fusion, bias remediation using Generative Adversarial Networks, and privacy-preserving federated learning, which address key challenges like diversity, personalization, and data security. By synthesizing existing research and identifying gaps, this work aims to guide future developments in creating robust, non-intrusive, and adaptive detection systems for diverse driving environments.

REVIEW ANALYSIS

To provide a comprehensive review of deep learning approaches for driver drowsiness detection, we conducted a systematic literature search on IEEE Xplore, PubMed, and SpringerLink, focusing on peer-reviewed articles from 2015 to 2024. Studies were included if they involved deep learning methods for drowsiness detection using behavioural, physiological, or hybrid approaches and reported empirical performance results. Exclusion criteria eliminated studies without deep learning applications, performance metrics, or peer-review. The search utilized Boolean queries like ("driver drowsiness detection" OR "driver fatigue") AND ("deep learning" OR "CNN" OR "GRU") and ("behavioural monitoring" OR "physiological signals"). Key data such as methodologies, data types, deep learning models, and evaluation metrics were extracted to evaluate advancements and research gaps in the field.

From the initial search, 30 peer-reviewed studies were selected, representing behavioural, physiological, and hybrid approaches. Critical details such as data types (e.g., facial

expressions, EEG, vehicular patterns), model architectures (e.g., CNNs, GRUs), and evaluation metrics were analyzed to assess innovation, empirical rigor, and real-world applicability. These studies provide a comprehensive overview of state-of-the-art techniques, highlighting strengths, limitations, and opportunities for advancing drowsiness detection systems.

The review is organized into four sections: comprehensive reviews on drowsiness detection techniques [1-5], behavioural measures [6-17], physiological measures [18-22], and advancements in systems and methodologies [23-30].

Comprehensive Surveys on Driver Drowsiness Detection Techniques

Sikander et al. reviewed driver fatigue detection technologies, stressing the need for real-time, robust, and accurate solutions, especially given the limitations of commercial systems like those from Volkswagen and Toyota [1]. They categorized detection features into subjective, biological, physical, vehicular, and hybrid measures. The study found physical features, when combined with contextual factors like time of day and driving duration, to be the most promising for non-intrusive, accurate applications. Ramzan et al. reviewed state-of-the-art drowsiness detection techniques, dividing them into behavioural, vehicular, and physiological methods [2]. Behavioural measures, such as yawning and eye closure, are non-invasive but sensitive to lighting and occlusions. Vehicular measures assess driving patterns, while physiological techniques use signals like EEG and ECG to detect fatigue. The authors highlighted the potential of machine learning models and multimodal systems for scalable solutions. Kolus et al. systematically reviewed 41 studies on eye activity-based drowsiness detection, including technologies like video oculography (VOG) and electrooculography (EOG) [3]. The review noted limitations such as small sample sizes and inconsistent performance metrics. Future directions include hybrid models combining multiple drowsiness measures and leveraging AI, IoT, and miniaturized sensors for better accuracy. Zhang et al. compared fatigue evaluation methods, contrasting standard techniques with machine learning approaches [4]. Standard methods monitor deviations in driver behavior, while machine learning techniques, like SVMs and NNs, classify drowsiness states using data from behavioural and physiological signals. The study recommended combining both approaches for personalized monitoring systems. Perkins et al. reviewed 130 studies, identifying challenges in driver drowsiness detection [5]. They emphasized hybrid methods that integrate physiological, behavioural, and vehicular data, but noted barriers like late detection, subject diversity, and inconsistent data collection. They stressed the importance of predictive

systems validated with real-world data and diverse participant groups, alongside addressing privacy concerns.

Together, these reviews offer a comprehensive view of driver drowsiness detection methods, highlighting the advantages and limitations of existing approaches. They emphasize the need for multimodal systems that combine behavioural, physiological, and vehicular measures to overcome challenges like intrusiveness and variability. Future research should refine hybrid models, validate them on real-world datasets, and address data inconsistencies and privacy issues to develop scalable and personalized solutions.

Literature Review on Behavioural Measures

Behavioural measures are widely used in driver drowsiness detection for their non-intrusiveness and ability to monitor physical signs like facial expressions and eye movements. These methods often employ computer vision and machine learning but face challenges in generalizability under real-world conditions.

Ramzan et al. proposed a 30-layer CNN architecture (CDLM) using the YawDD dataset, achieving 99.7% binary and 99.4% ternary classification accuracy after 60 epochs [8]. The hybrid model combining CNN with HOG and PCA reached 98.8% overall accuracy but suffered from computational expense, limiting real-time scalability. Huang et al. introduced RF-DCM, achieving 89.42% accuracy on the NTHU dataset, but its reliance on facial features made it less effective under poor lighting or partial occlusion [9]. Vijaypriya et al. optimized a Multi-Scale CNN with the Flamingo Search Algorithm, achieving 98.38% and 98.26% accuracy on the YawDD and NTHU-DDD datasets, respectively, but computational complexity hindered real-time use [10].

Deng et al. developed a real-time CNN-KCF system for tracking facial features, achieving 92% accuracy but struggling with dim lighting and occlusion [11]. Yang et al. proposed a video-based CSP algorithm with the TB-MHA module for spatial-temporal feature extraction, showing superior accuracy on YawDD, NTHU-DDD, and VBDDD datasets [12]. Tamanani et al. created a low-cost real-time system using image processing and deep learning, achieving 91.8% accuracy on UTA-RLDD and 98% under varying lighting with transfer learning [13].

Madni et al. used transfer learning with VGG-16 and LGBM, reaching 99% accuracy and detecting drowsiness in 0.00829 seconds, making it suitable for real-time use [14]. Nguyen et al. developed a lightweight CNN system for eye status recognition at 33.12 FPS on Nvidia Jetson Nano, designed for low-computing devices [15]. Jordan et al. embedded a CNN-based solution in smart glasses, improving accuracy

by 7% over traditional methods but with higher battery and memory consumption [16]. Yang et al. introduced FatigueView, a multi-camera dataset with RGB and infrared recordings, enabling models to address real-world challenges like lighting and demographics [17].

Behavioural measures, particularly those using CNNs and GRUs, demonstrate high accuracy under controlled conditions. However, challenges such as environmental sensitivity, camera angles, and facial feature variability remain barriers to broader real-world application. Despite these hurdles, behavioural measures are a promising avenue for enhancing in-vehicle drowsiness detection systems.

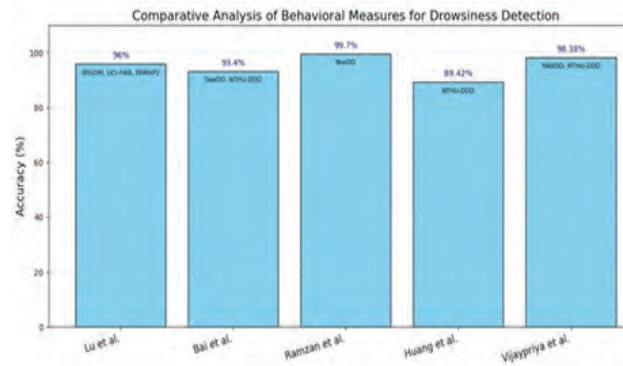


Fig. 2. Comparative Analysis of Behavioral Measures for Driver Drowsiness Detection: Accuracy and Dataset Overview

Fig. 2 presents a comparative analysis of various behavioural measures used in driver drowsiness detection, highlighting the accuracy and datasets associated with each method.

Literature Review on Physiological Measures

The study by Alguindigue et al. focused on detecting driver drowsiness using heart rate variability (HRV) and electrodermal activity (EDA) with deep learning models like sequential neural networks and convolutional recurrent neural networks. Their method achieved high precision with HRV (98.28%) and EDA (96.32%), but eye-tracking data showed lower performance due to data imbalance and artificial driving conditions. They suggested integrating additional physiological signals to improve accuracy [18]. Shahbakhti et al. developed an algorithm for simultaneous extraction and elimination of eye blink features from low-channel prefrontal EEG signals using variational mode extraction (VME), PCA, and DWT. This approach improved mean detection accuracy from 71.2% to 78.1% ($p < 0.05$), emphasizing the dual role of eye blinks as both informative signals and artifacts in EEG-based detection [19].

Picot et al. proposed a hybrid drowsiness detection system combining EEG and EOG signals via a cascading decision-

making approach. The system prioritized EEG for early signs of drowsiness and EOG for confirmation, achieving 80.6% accuracy. Despite its robustness and driver independence, the study noted the intrusiveness of EEG and EOG sensors and highlighted the potential of video-based analysis for less invasive monitoring [20]. Tang et al. introduced the attention-guided MSCNN-CAM model for EEG-based driver fatigue detection, which leveraged multiscale convolutional branches and a Channel Attention Module to prioritize channel relevance. This model achieved a correlation coefficient of 0.966 and demonstrated strong potential for real-time non-invasive monitoring, though challenges like computational demands remain [21].

Tanveer et al. employed functional near-infrared spectroscopy (fNIRS) with deep learning, achieving up to 99.3% accuracy using CNNs. While promising, limitations included a small participant pool and high computation times, with suggestions to integrate fNIRS with other non-invasive methods for improved applicability [22]. Comparative analysis highlighted the high accuracy of these approaches, with MSCNN-CAM (98.28%) and fNIRS-CNN (99.3%) models leading the results, though issues such as dataset limitations, real-time adaptability, and sensor intrusiveness persist. Future advancements may lie in integrating diverse physiological signals and non-intrusive methods like video analysis to enhance detection systems' robustness and user-friendliness.

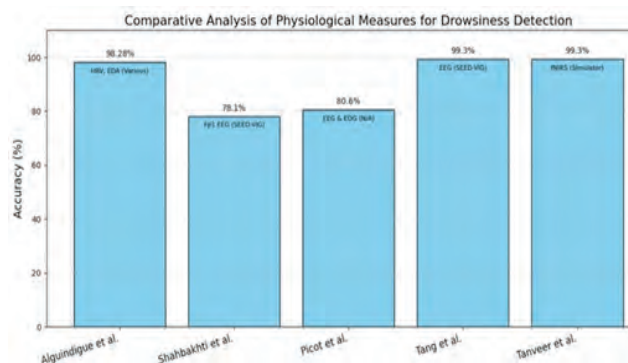


Fig. 3. Comparative Analysis of Physiological Measures for Driver Drowsiness Detection

Fig. 3 illustrates a comparative analysis of various physiological measures used for driver drowsiness detection, showcasing the accuracy percentages achieved by different studies.

Literature Review on Advancements in Driver Drowsiness Detection

The field of driver drowsiness detection has made significant

progress through multimodal data fusion, personalized models, and privacy-preserving frameworks, addressing issues like bias, real-time application, and early detection. Recent studies highlight innovative approaches, strengths, and limitations, offering insights for future research.

- 1) **Multimodal Approaches for Drowsiness Detection:** Qian et al. developed a multimodal system using environmental data (temperature, humidity, illuminance) and human activity data for non-invasive detection. While generalizable due to real-world data, its moderate recall (64.6%) highlights the need for larger datasets and algorithm refinement [23]. Sunagawa et al. incorporated blink and posture information to detect all drowsiness stages, including weak stages often missed by traditional methods, but achieved a low F1-score (53.6%), signaling further exploration of multimodal robustness is needed [24].
- 2) **Optimization of Machine Learning Architectures:** Jebraeily et al. optimized CNN architectures with genetic algorithms (GA), achieving high accuracy on labeled image datasets. However, addressing early-stage drowsiness remains challenging due to image-only reliance, suggesting the integration of physiological or behavioral data [25].
- 3) **Privacy-Preserving and Bias-Remediation Strategies:** Zhang et al. proposed a federated transfer learning framework with homomorphic encryption, improving accuracy on NTHU-DDD and YAWDD datasets while preserving privacy. However, computational overhead limits scalability [26]. Ngxande et al. reduced biases in detection systems using GAN-generated synthetic datasets, enhancing fairness across demographics. While effective, reliance on synthetic data necessitates further real-world validation [28].
- 4) **Personalized and Real-Time Solutions:** You et al. introduced a real-time detection algorithm tailored to individual drivers by adjusting predictions based on eye aspect ratio (EAR). This personalized system achieved 94.8% accuracy at over 20 frames per second but raised scalability concerns due to pre-training requirements [29].
- 5) **Advancements in Physiological Signal Processing:** Zhang et al. utilized multi-channel SOBI for physiological signal analysis (EEG, EOG, EMG), achieving 90% accuracy and demonstrating robustness against external factors like lighting and posture. However, reliance on specialized equipment limits widespread adoption [30].

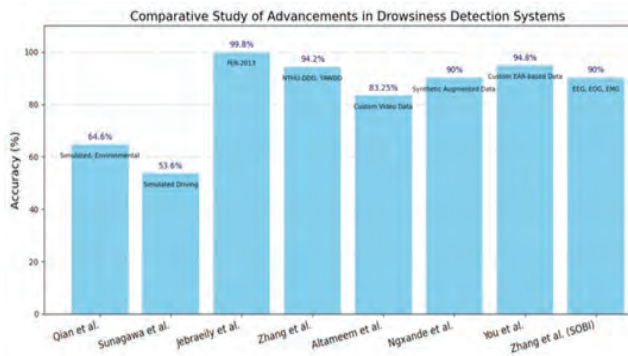


Fig. 4. Comparative Analysis of Advancements in Driver Drowsiness Detection Systems

Figure 4 provides a comparative analysis of advancements in driver drowsiness detection systems based on reported accuracy percentages and datasets used.

CONCLUSIONS

The integration of physiological measures, such as EEG and ECG, with behavioural measures derived from facial recognition technology presents a promising approach for driver drowsiness detection. This combination harnesses the strengths of both modalities, offering reliable and accurate detection through objective physiological data and observable behavioural cues. However, challenges remain, including the intrusiveness of physiological sensors and the potential privacy concerns associated with facial recognition. Additionally, ensuring that detection systems remain robust in the face of environmental factors, variations in lighting, and individual differences continues to be a significant hurdle.

To address these challenges, future research should focus on developing less intrusive and more user-friendly sensor technologies while incorporating privacy-preserving techniques for facial recognition. Personalized models that can adapt to individual differences in drowsiness patterns should also be prioritized to improve detection accuracy and reduce false alarms. Furthermore, exploring the integration of additional indicators, such as head pose analysis or steering grip, could enhance the comprehensiveness and robustness of drowsiness detection systems. Advancing these areas will be crucial for creating real-time, scalable, and effective drowsiness detection solutions that contribute to road safety and reduce the risk of accidents caused by driver fatigue. By addressing these challenges and pursuing innovative strategies, future drowsiness detection systems will be better positioned to meet the needs of diverse driving environments and individual drivers, leading to safer and more reliable roads.

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Automated Information Retrieval System for Equity Research Analysis Using LLM

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ABSTRACT

This project focuses on building an Automated Information Retrieval System to help with Equity Research Analysis using Large Language Models (LLMs). The system uses advanced natural language processing (NLP) to make financial data analysis faster and more accurate. It gathers, analyzes, and summarizes data from sources like news and reports. Key features include real-time data collection, cleaning, vector embeddings using FAISS, and summarization using Hugging Face and Google PaLM. With Retrieval-Augmented Generation (RAG), the system gives precise responses and keeps improving by adding new features. It is hosted on platforms such as Hugging Face Spaces, ensuring ease of access and scalability. This helps analysts make smarter investment choices in fast-changing financial markets.

KEYWORDS : *Automated information retrieval, LLM, Hugging face, NLP, RAG, FAISS, Model deployment.*

INTRODUCTION

In the fast-paced world of finance, staying on top of the constant flow of information is important but challenging. Financial analysts need to keep track of many data sources, like news articles and financial reports, to make informed investment decisions. This task is time-consuming and prone to mistakes, especially when dealing with large amounts of unstructured data manually. To solve this problem, our project focuses on creating an Automated Information Retrieval System for Equity Research Analysis. The goal is to automate the process of collecting, processing, and summarizing financial data, so analysts can spend less time on research and more on strategic decision-making. When asked a question like “What is the educational background of the current president of the United States?”, the system first gathers key facts like “The current president of the United States is Joe Biden” and “He graduated with a Bachelor of Arts degree from the University of Delaware in 1965,” as well as extra details like his law degree and honorary degrees. It then uses this information to answer the question. Automated Information Retrieval technology helps collect and summarize financial news and reports in real time. By using Large Language Models (LLMs) like GPT and Llama,

the system processes large volumes of data and provides clear insights quickly. This improves financial decision-making by giving accurate, up-to-date information, which saves time and reduces the chances of human error. The use of RAG ensures more relevant and precise data, helping analysts make smarter, faster investment decisions [6].

RELATED WORKS

Advancements in deep learning models and cutting-edge algorithms have significantly transformed the domain of automated information retrieval. These technologies have unlocked new possibilities in analyzing large-scale data, enabling faster, more accurate insights across various fields. In the realm of equity research analysis, the integration of such tools has proven invaluable for extracting, processing, and interpreting complex financial data. This section highlights the key publications, methodologies, and technological progress associated with developing automated systems for equity research analysis, emphasizing their role in enhancing decision-making, streamlining workflows, and delivering actionable intelligence in the financial sector.

The paper “FundRecLLM - Fund Recommendation Based on Financial News and Research Analyst Reports” explores

the use of large language models (LLMs) like ChatGPT and PaLM for analysing financial news and reports to recommend industry funds. While LLMs proved effective, challenges arose in integrating diverse information. Future improvements could focus on better handling of the report's beginning sections to improve accuracy [1].

“Unleashing the Power of Large Language Model, Textual Embeddings, and Knowledge Graphs for Advanced Information Retrieval” presents a system that combines LLMs, textual embeddings, and knowledge graphs to improve Q&A systems. This method addresses limitations in traditional systems by enhancing contextual understanding and entity representation, enabling it to handle complex, multi-entity queries [2].

The paper “Hybrid Retrieval-Augmented Generation Approach for LLMs Query Response Enhancement” discusses Hybrid RAG, which enhances language models by integrating external data. While it improves answer accuracy, challenges include computational demands and dependence on potentially outdated data, limiting its reliability for complex queries [4].

The “A Multi-Source Retrieval Question Answering Framework Based on RAG” paper introduces MSRAG, which combines GPT-3.5 and web retrieval to improve the relevance of answers. By efficiently ranking and filtering retrieved documents, MSRAG reduces irrelevant data, enhancing response accuracy and precision in QA systems [9].

In “RAG-based LLM Chatbot using Llama-2,” Sonia Vakayil et al. present a chatbot designed to assist sexual harassment victims by combining empathy with legal guidance. The system leverages Llama-2, integrated with a Retrieval-Augmented Generation (RAG) model, to provide personalized responses by retrieving relevant information from ChromaDB using cosine similarity. The chatbot focuses on ensuring victims feel supported while delivering accurate legal information tailored to their needs. Although it demonstrates potential for applications in mental health and trauma care, limitations include a lack of full cloud accessibility and support for male victims. The study highlights the capabilities of LLMs in creating specialized support systems for addressing sensitive issues effectively.

Authors & Year of Publication	Methodology Adapted
Guang Yang et al. (2023)	Used large language models (ChatGPT, PaLM) for fund recommendations based on financial news and analyst reports.

Divyanshi Yadav et al. (2023)	Combined LLMs, textual embeddings, and knowledge graphs to enhance Q&A systems for better handling of complex queries.
Pouria Omrani et al. (2024)	Hybrid Retrieval-Augmented Generation (RAG) method for improving query responses by retrieving useful data and refining it.
Ridong Wu et al. (2024)	Introduced MSRAG, combining GPT-3.5 and web retrieval to enhance QA by ranking and filtering documents using cosine similarity.
Sonia Vakayil, et al. (2024)	Self-Retrieval model that integrates indexing, retrieval, and self-assessment within an LLM to improve information retrieval and Q&A tasks.

METHODOLOGY

Data is gathered from various financial sources such as company reports, market news, and analyst insights. This data is then cleaned, organized, and standardized to ensure consistency. Text data is broken down into smaller chunks, which helps improve the accuracy of information retrieval and ensures the system can provide contextually appropriate results when a query is made.

Once the data is preprocessed, it is converted into vector embeddings and stored in a FAISS (Facebook AI Similarity Search) database. FAISS enables quick search and indexing of large datasets by transforming text into numerical vectors. When a query is submitted, FAISS compares these vectors to find and retrieve the most relevant data quickly.

The key technique used is Retrieval-Augmented Generation (RAG). For example, if a query like “What are the latest equity trends for Company X?” is inquired, FAISS recovers the most significant information chunks. RAG then combines this data with the context of the query to generate a more precise and informative response. After the data is retrieved, Large Language Models (LLMs) such as those from Hugging Face or OpenAI analyze the content and provide a coherent, contextually aware response.

The LLM uses both the user's query and the retrieved data to generate a detailed and accurate response, ensuring it is contextually relevant. The system is deployed on Hugging Face Spaces, making it easily accessible to financial analysts. This deployment provides real-time, reliable insights with minimal technical effort required. Additionally, the cloud-

based setup allows the system to scale, handling increased query volume as the demand grows.

The system features a user-friendly Streamlit interface for examiners to input queries and view results. It begins with Document Ingestion, where various document types (e.g., PDFs, articles, URLs) are imported using libraries like TextLoader and UnstructuredURLLoader. These documents are then split into manageable chunks using Character TextSplitter or Recursive TextSplitter, ensuring context preservation. Next, these chunks are converted into vector embeddings and stored in a Vector Database using FAISS, enabling efficient similarity searches. During the Retrieval phase, relevant chunks are identified using Retrieval QA With Sources Chain based on query similarity.

Finally, the retrieved chunks and user query are sent to a pre-trained Large Language Model (LLM) from Hugging Face, which generates structured, contextually accurate responses supported by the source content.

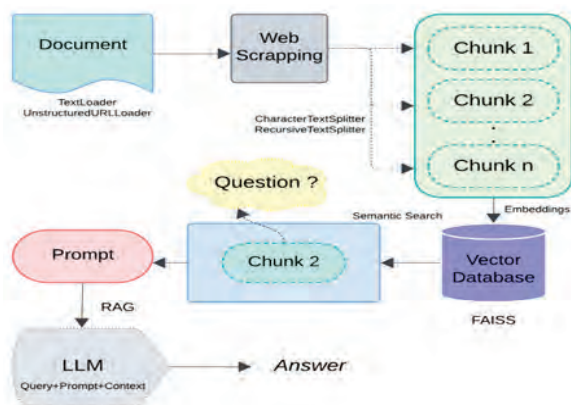


Fig. 1: Methodology

The MapReduce method breaks down large financial data into smaller chunks, each processed by separate LLMs to extract relevant information. The filtered outputs from each chunk are then merged into a summary that matches the user's query. Finally, a main LLM synthesizes this summary to generate a precise answer. This approach improves efficiency, accuracy, and scalability, making it ideal for handling complex equity analysis tasks.

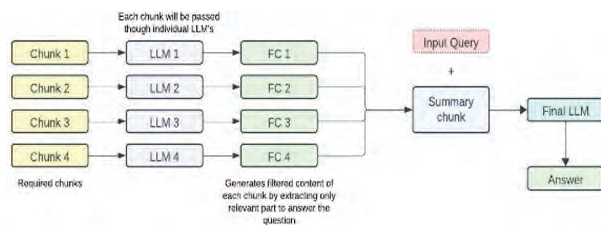


Fig. 2: Algorithm used: Mapreduce Method

MATHEMATICAL MODEL

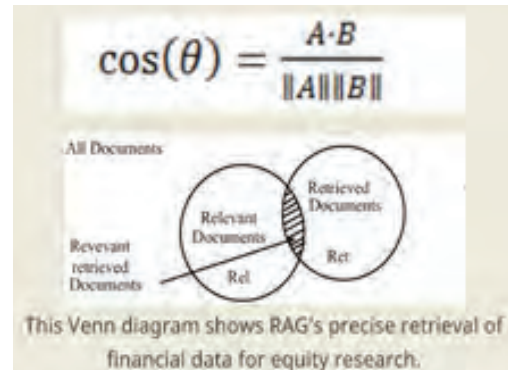


Fig. 3: Cosine Similarity

The system uses cosine similarity to measure how closely document chunks match the query, ensuring the most relevant chunks are retrieved. By combining this approach with Retrieval-Augmented Generation (RAG), the system enhances response accuracy and relevance. This method is especially beneficial for data-heavy fields like financial analysis, where precision and context are critical.

RESULT ANALYSIS

The system is expected to make finding financial information fast, so analysts won't have to spend as much time searching. It will save about 60% of the time they usually spend on research.

-By using RAG and LLMs, the system will give more accurate financial insights. It will find the most important pieces of data and understand them better, so the answers to questions will be more accurate.

-With FAISS, the system will be able to search through large financial data fast. Users will be able to find specific details, trends, or insights quickly, without having to do a lot of work themselves.

-By using the platform Hugging Face Spaces, the system will give analysts quick access to the latest financial info. They can ask questions and get answers right away, helping them make decisions faster.

-The system will be easy to use, even for people who aren't very tech-savvy. This means more people, from analysts to executives, will be able to use it without any trouble.

-The system will automate most of the report generation by gathering data from different sources, so analysts can spend more time making smart decisions instead of dealing with data. This will make their work easier, faster, and more focused on what truly matters.

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Investigation of Deviations from Classical Metric Space

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ABSTRACT

The objectives of the research is to assemble and recall the abundant class of Metric space innovated. The beginning was Metric space invented by Maurice Fréchet. We attempt to abridge the works of various researchers in this discipline. The paper is divided into the time periods showcasing the invention of variants of Metric space in that particular era.

KEYWORDS : contraction mapping, C_P^ψ - rational contraction, Fuzzy b-Metric space, parametric S-MS, Extended Parametric Sb-Metric space.

INTRODUCTION

Metric space are a fundamental topic of research in fixed point theory, with their study originally initiated by Maurice Fréchet in 1906. A MS is a structure composed of a set of elements and a distance function that defines the distance between any two elements within the set. [1]

THE FOUNDATION 1906

Metric Space: [2] A MS is a set $\mathfrak{P}$ armed with a function

$d: \mathfrak{P} \times \mathfrak{P} \rightarrow \mathbb{R}$ titled a metric or distance function, which gratifies assets $\forall \zeta, \vartheta, \xi \in \mathfrak{P}$

$$d(\zeta, \vartheta) \geq 0$$

$$d(\zeta, \vartheta) = 0 \text{ iff } \zeta = \vartheta$$

$$d(\zeta, \vartheta) = d(\vartheta, \zeta)$$

$$d(\zeta, \xi) \leq d(\zeta, \vartheta) + d(\vartheta, \xi)$$

$(\mathfrak{P}, d)$ termed as MS.

Example: [3] Let $\mathfrak{P} = \mathbb{R}$ with $d(\zeta, \vartheta) = |\zeta - \vartheta|, \forall \zeta, \vartheta \in \mathfrak{P}$.

Maurice Fréchet Early 20th century (1906) also make known to the pseudo MS. A pseudo MS is similar to a MS but then allows for the distance between two distinct points to be zero.

THE PERIOD 1910-1930

The term “contractive mapping” was initially introduced by Edelstein [4] intended for the MS.

Contraction Mapping [5]: If $(\mathfrak{P}, d)$ is a MS then $q: \mathfrak{P} \rightarrow \mathfrak{P}$ is contractive mapping if $d(qx, qy) < d(x, y), \forall x, y \in \mathfrak{P}$.

This period was proved very crucial due to work of Stefan Banach (1922) famous as Banach Contraction Principle stated as:

Banach Contraction Principle [6]: If $\mathfrak{P}$ is a complete MS and $q: \mathfrak{P} \rightarrow \mathfrak{P}$ is a contraction map, then q has a unique fixed point.

Also, the famous Brower fixed point theorem is developed in 1912 was stated as, “Let A is closed ball in $\mathbb{R}^n$. Then any continuous map defined on A has at least one fixed point.”

THE PERIOD 1930-1950

Wilson [7] introduced the MS lacking symmetric condition, which is termed as quasi-MS (1931)

Quasi-MS: [7] A function $d: \mathfrak{P}^2 \rightarrow \mathbb{R}^+ \cup \{0\}$ where $(\mathfrak{P} \neq \emptyset)$ is well known as a quasi-metric if circumstances hold:

$$(i) d(\zeta, \zeta) = 0, \forall \zeta \in \mathfrak{P}$$

$$(ii) d(\zeta, \vartheta) = 0 \Rightarrow \zeta = \vartheta$$

$$(iii) d(\zeta, \xi) \leq d(\zeta, \vartheta) + d(\vartheta, \xi), \forall \zeta, \vartheta, \xi \in \mathfrak{P}$$

Metric space	Pseudo-MS	Quasi-MS
Distance is zero only for equal elements	distance between distinct points may be zero	Distance zero implies elements are equal

THE PERIOD 1950-1970

Probabilistic MS was introduced by B. Schweizer and A. Sklar in research work “Statistical Metric space.” (1960)

In “the study of probabilistic metric space,” the notion of distance between points is well-defined in terms of probability distributions rather than fixed real numbers. This approach

is advantageous in probabilistic analysis and applications consisting ambiguous conclusions.

Probabilistic MS: [8] If $\mathfrak{P}$ is an abstract set in $(\mathfrak{P}, \varrho)$ along with mapping $\varrho: \mathfrak{P} \times \mathfrak{P} \rightarrow \text{set of distribution functions}$. Here $\varrho(\zeta, \vartheta) = \varrho_{\zeta\vartheta}$ is a distribution function associated with every pair (ζ, ϑ) of points in $\mathfrak{P}$. $\varrho_{\zeta\vartheta}(\xi)$ will denote it's the value for the real argument ξ , wherein

- (i) $\varrho_{\zeta\vartheta}(\xi) = 1, \forall \xi > 0$
- (ii) $\varrho_{\zeta\vartheta}(0) = 0$
- (iii) $\varrho_{\zeta\vartheta} = \varrho_{\vartheta\zeta}$
- (iv) If $\varrho_{\zeta\vartheta}(\xi) = 1$ & $\varrho_{\zeta\varpi}(\eta) = 1 \Rightarrow \mathcal{F}_{pr}(\xi + \eta) = 1$

The idea of a 2-MS was acquainted with by Gähler via triangle area as a rousing instance. Gähler demonstrated that in a 2-metric, the metric d is non-negative. Following Gähler's work, numerous authors have contributed a wealth of new results in these spaces. Its applications extend to various fields like military, medicine, and economics. [9], [10]

In 1968, Kannan [11] evidenced an extension of Banach by eradicating continuity condition of the map famous as Kannan Contraction.

THE PERIOD 1970-1990

Theory of Fuzzy Sets was invented by Lotfi A. Zadeh, 1965. While Fuzzy MS was formed by Kramosil and Michalek in 1975. This space covers the idea of Metric space by incorporating the thought of fuzziness, which allows for the measurement of distances to be represented by fuzzy sets, capturing the inherent uncertainty in many real-world scenarios. One significant advancement is the idea of fuzzy Metric space. It handles situations of uncertainty and vagueness. Fuzzy Metric space allow the distance allocated to fuzzy number rather than a real number, providing a more flexible framework for certain types of problems.

Fuzzy MS (1975): [13] Assume continuous t-norm W , along with non-empty set $\mathfrak{P}$. If B is a fuzzy set on $\mathfrak{P}^{2 \times} (0, \infty)$. Then $(\mathfrak{P}, B, W)$ is fuzzy MS if $\forall \varpi, \eta > 0$ & $\forall \zeta, \vartheta, \xi, \varpi, \eta \in Y$, following conditions hold:

- (i) $B(\zeta, \vartheta, \varpi) > 0$
- (ii) $B(\zeta, \vartheta, \varpi) = 1 \Leftrightarrow \zeta = \vartheta$
- (iii) $B(\zeta, \vartheta, \varpi) = B(\vartheta, \zeta, \varpi)$
- (iv) $W(B(\zeta, \vartheta, \varpi), B(\vartheta, \xi, \eta)) \leq B(\zeta, \xi, \eta + \varpi)$
- (v) $B(\zeta, \vartheta, .): (0, \infty) \rightarrow [0, 1]$ is continuous.

Example: [13]. Let $B: \mathfrak{P} \times \mathfrak{P} \times \mathcal{R}^+ \cup \{0\} \rightarrow [0, 1]$ and define B for all $\xi \geq 0$, by

$$B(\zeta, \vartheta, \xi) = \frac{\min\{\zeta, \vartheta\} + \xi}{\max\{\zeta, \vartheta\} + \xi}, \forall \zeta, \vartheta \in \mathfrak{P}$$

Then B is a fuzzy metric.

In 1984, Khan [14] well-defined "control function" The conception was evidenced vital in M.S. It is also acknowledged as an altering distance functions.

THE PERIOD 1990-2010

The concept of a b-MS, as it is widely recognized today, was indeed introduced by Stefan Czerwik (1993). Czerwik defined a b-MS as a generalization of a MS with a relaxed triangle inequality condition involving a constant $s \geq 1$. This generalization has since been used in various mathematical studies and applications.

b-MS[15]: Let $\mathfrak{P}$ be a space. Let $\mathcal{R}^+$: set of nonnegative reals. A function $d: \mathfrak{P} \times \mathfrak{P} \rightarrow \mathcal{R}^+$ is b-metric if for all $\zeta, \vartheta, \xi \in \mathfrak{P}$ following conditions hold:

- (i) $d(\zeta, \vartheta) = 0 \text{ iff } \zeta = \vartheta$
 - (ii) $d(\zeta, \vartheta) = d(\vartheta, \zeta)$
 - (iii) $d(\zeta, \vartheta, \xi) \leq s[d(\zeta, \vartheta) + d(\vartheta, \xi)]$
- A pair $(\mathfrak{P}, d)$ is called a b-MS.

Examples: [16] Let $(\mathfrak{P}, \rho)$ is a b-MS. $\rho(\zeta, \vartheta) = (d(\xi, \varpi))^k$ Where $k > 1$ is a real number and d is a usual metric. Then ρ is a b-metric with $b = 2^{k-1}$.

The 2-MS was not continuous or convergent for all three points. So Dhage [17] presented the new metric as D -metric.

D-MS: (1994) [17]

A real function d on $\mathfrak{P} \times \mathfrak{P} \times \mathfrak{P}$ is said to be a D -metric on $\mathfrak{P}$ if

- (i) $d(\zeta, \vartheta, \xi) \geq 0, \forall \zeta, \vartheta, \xi \in \mathfrak{P}$
- (ii) $d(\zeta, \vartheta, \xi) = 0 \text{ iff } \zeta = \vartheta = \xi$
- (iii) $d(\zeta, \vartheta, \xi) = d(p(\zeta, \vartheta, \xi))$ for every $\zeta, \vartheta, \xi \in \mathfrak{P}$ and for any permutation $p(\zeta, \vartheta, \xi)$ of ζ, ϑ, ξ
- (iv) $d(\zeta, \vartheta, \xi) \leq d(\zeta, \vartheta, \varpi) + d(\zeta, \varpi, \xi) + d(\varpi, \vartheta, \xi) \forall \zeta, \vartheta, \xi, \varpi \in \mathfrak{P}$

The pair $(\mathfrak{P}, d)$ is D -MS.

Partial MS was developed by Steve G. Matthews (1994) in one of the research works "Partial Metric Topology" published

in: Annals of the New York Academy of Sciences. Wherein Matthews developed the notion of partial Metric space to provide a more generalized framework for distance measurement, which is particularly applicable in theoretical computer science.

Partial MS (1994): [18] Let $\mathfrak{P}$ is non-empty set along with function $d: \mathfrak{P} \times \mathfrak{P} \rightarrow \mathcal{R}^+$ so as $\forall \zeta, \vartheta, \xi \in \mathfrak{P}$

- (i) $\zeta = \vartheta$ iff $d(\zeta, \zeta) = d(\zeta, \vartheta) = d(\vartheta, \vartheta)$
- (ii) $d(\zeta, \zeta) \leq d(\zeta, \vartheta)$
- (iii) $d(\zeta, \vartheta) = d(\vartheta, \zeta)$
- (iv) $d(\zeta, \vartheta) \leq d(\zeta, \xi) + d(\xi, \vartheta) - d(\xi, \xi)$

Thus, the pair $(\mathfrak{P}, d)$ displays partial MS.

Note: MS, quasi MS, b-MS, partial metric defined on ordered pair. Whereas D-metric, Fuzzy metric, 2-metric operates on triplets. Subsequently another significant generalization is the Modular MS. Shioji and Takahashi introduced this thought in the research “Fixed Point Theorems in Modular Space” Proceedings of the American Mathematical Society. As well Shioji and Takahashi explored fixed point theorems within the context of modular spaces, providing a foundation for further developments and applications of modular Metric space.

A Modular MS is the generalization of MS that includes a positive parameter.

Modular MS: [19] A function $d: (0, \infty) \times \mathfrak{P} \times \mathfrak{P} \rightarrow [0, +\infty)$ “is called a modular metric on $\mathfrak{P}$ if the following” axioms hold:

- (i) $\zeta = \vartheta$ iff $d_\lambda(\zeta, \vartheta) = 0, \forall \lambda > 0$
- (ii) $d_\lambda(\zeta, \vartheta) = d_\lambda(\vartheta, \zeta), \forall \lambda > 0 \ \& \ \zeta, \vartheta \in \mathfrak{P}$
- (iii) $d_{\lambda+\mu}(\zeta, \vartheta) \leq d_\lambda(\zeta, \xi) + d_\mu(\xi, \vartheta), \forall \lambda, \mu > 0 \text{ and } \forall \zeta, \vartheta, \xi \in \mathfrak{P}$

A modular metric d on $\mathfrak{P}$ is called regular if (i) is satisfied: $\zeta = \vartheta$ iff $\xi_\lambda(\zeta, \vartheta) = 0$ for some $\lambda > 0$.

After the development of modular Metric space, several other generalizations and extensions of Metric space have been studied.

Neill [20] extended range of partial metric” from $[0, \infty)$ to $(-\infty, \infty)$. Thus, partial metric p with extended range is known as dualistic” partial metric (1996) [21] In 2002 Branciari introduced the notion of integral type contraction which was basically developed from Banach contraction principle [22]. Following Branciari many researchers worked on integral type contraction mapping. [23]. While Suzuki (2007) ”introduced the weaker C-contractive condition and gained fixed point” theorems [24]. Also authors [12] worked on Generalized (ψ, α, β) -weak contractions. While authors [40] worked on Integral Type Rational Contraction.

C- Condition: Let $(\mathfrak{P}, d)$ is a MS. Let map $\varrho: \mathfrak{P} \rightarrow \mathfrak{P}$ gratifies the C-condition if, for all $\zeta, \vartheta \in \mathfrak{P}$

$$\frac{1}{2}d(\zeta, \varrho\zeta) \leq d(\zeta, \vartheta) \Rightarrow d(\varrho\zeta, \varrho\vartheta) \leq d(\zeta, \vartheta)$$

The framework of rectangular Metric space was introduced by Branciari in 2000 [25]. Wherein the triangle inequality changes to rectangular consists of four points as follows.

Rectangular MS: [25]

Let $\mathfrak{P}$ be a non-empty set. Let $d: \mathfrak{P}^2 \rightarrow [0, \infty)$ is rectangular metric on $\mathfrak{P}$ if for any $\zeta, \vartheta, \xi, \varpi \in \mathfrak{P}$, and all distinct points $\xi, \varpi \in \mathfrak{P} \setminus \{\zeta, \vartheta\}$

1. $\zeta = \vartheta$ iff $d(\zeta, \vartheta) = 0$
2. $d(\zeta, \vartheta) = d(\vartheta, \zeta)$
3. $d(\zeta, \vartheta) \leq d(\zeta, \xi) + d(\xi, \varpi) + d(\varpi, \vartheta)$

The pair $(\mathfrak{P}, d)$ is called a rectangular MS.

Note: In MS and b-MS triangle inequality is defined for three points while in rectangular metric it is defined for four points. Due to which it’s named as rectangular metric. Successively Fuzzy Quasi MS (2004) was invented [26] was modified. G-Metric space well-defined by Mustafa and Sims (2004) in one of the research works [27]. Authors widespread it by incorporating a three-variable function, providing a framework suitable for fixed-point theory and other applications. Thus, MS and b-M.S., modular metric, Partial metric, rectangular metric are two variable functions while G-MS, D-M.S. and Fuzzy are three variable functions.

THE PERIOD 2010-2024

The “idea of complex-valued Metric space was introduced by K. Azam” and his collaborators in the paper “Complex Valued Metric space and Fixed-Point Theorems” published in 2011. Here in Complex Valued Metric space codomain is set of complex numbers. Hussain” and Shah introduced the concept of cone” b-Metric space in their research paper titled “Cone b-Metric space and fixed-point theorems” [28]. In the research, they extended the classical notion of Metric space by employing cone b-Metric space and studied various properties and fixed-point theorems within this framework. The research contributes to the broader field of general MS theory and its applications in mathematical analysis. Rao et al (2013) [29] acquainted with complex valued b-Metric space. Satish Shukla (2013) [30] formed sandwich of partial metric and b-Metric space results into partial b-MS. Fuzzy b-Metric

space were introduced by Irfan Deli and Oktay Duman (2014) [13]. These spaces generalize fuzzy Metric space by incorporating a parameter b , which allows for greater flexibility in defining the distance function. George et al. (2015) added a parameter to acquire rectangular b-MS in the rectangular MS. In 2017, Kamran et al. (2017), widespread the framework of extended b-Metric space [31]. Hassen et al [32] presented new extended b-MS by altering the domain of the function X from $X \times X$ to $X \times X \times X$ in the extended b-MS.

M.E. Ege, C. Alaca (2018) introduced the concept of Modular b-MS through one of the research work.

Modular b-MS: [19]

Assume non-empty set P along with real no. $s \geq 1$. A map $d: (0, \infty) \times \mathfrak{P} \times \mathfrak{P} \rightarrow [0, \infty)$ is modular b-metric, if succeeding statements hold: $\forall \zeta, \theta, \xi \in \mathfrak{P}$

$$d_\lambda(\zeta, \theta) = 0 \text{ for all } \lambda > 0 \Leftrightarrow \zeta = \theta$$

Type of MS	Invention Year	Researchers Name
MS, Pseudo M.S.	1906	M. Fréchet
Quasi M.S.	1931	W. A. Wilson
Probabilistic M.S.	1960	B. Schweizer, A. Sklar
Fuzzy M.S.	1975	Kramosil & Michalek
D-M.S.	1994	Dhage
Dualistic Partial M.S.	1996	S.J. O'Neil
Rectangular M.S.	2000	A. Branciari
G-M.S.	2004	Z. Mustafa, B. Sims,
Fuzzy Quasi M.S.	(2004)	Gregori & Romaguera
Cone M.S.	2007	Huang and Zhang
Complex-valued M.S.	2011	K. Azam
Cone b-M.S.	2011	N. Hussain, M.H. Shah
Complex valued b-M.S.	2013	Rao et al
Partial b-M.S.	2013	S. Shukla
Fuzzy b-M.S.	2014	O. Duman
Rectangular b-M.S.	2015	George et al.
Parametric b-M.S.	2015	N. Hussain, P. Salimi & V. Parvaneh
Sb-M.S.	2016	S. Sedghi, A. Gholidahneh, T. Dosenovic, J. Esfahani, and S. Radenovic
Parametric S-M.S.	2016	N. Tas and N. Y. Ozgur
Extended b-M.S.	2017	M. Samreen, T. Kamran, and KutubUl A
Modular b-M.S.	2018	M.E. Ege, C. Alaca

Parametric Sb-M.S.	2018	N. Tas and N. Y. Ozgur
Extended rectangular b-M.S.	2019	M. Asim, M. Imdad, and S. Radenovic
New extended b-M.S.	2019	H. Aydi, A. Felhi, T. Kamran, E. Karapınar and M. Ali
Extended Parametric Sb-M.S.	2023	N. Mani, S. Beniwal, R. Shukla and M. Pingale
Bipolar Parametric M.S.	2024	M. Pasha, K. K. Rao, G. Mani, A. Gnanaprakasam, and S. Kumar
F modular b-M.S.	2024	P. Tyagi, S. Chauhan, N. Mani and R. Shukla
G_b M.S.	2024	S. Pakhira, SkHossein

$$d_\lambda(\zeta, \theta) = d_\lambda(\theta, \zeta) \text{ for all } \lambda > 0$$

$$d_{\lambda+\mu}(\zeta, \theta) \leq s[d_\lambda(\zeta, \xi) + d_\mu(\xi, \theta)] \forall \lambda, \mu > 0$$

Formerly $(\mathfrak{P}, d)$ is a modular b-MS.

Extended rectangular b-Metric space successfully designed by A sim and coauthors (2019) [33]

MS $\rightarrow$ b-MS $\rightarrow$ Rectangular.b-MS $\rightarrow$ Extended rectangular b-MS

For variants the foundation concept was MS. In the settings of Metric space author introduced the parameter s to make it more flexible. While in complex valued Metric space domain is set of complex numbers. While in extended Metric space parameter s is replaced by function θ . Hussain et al. (2015) [34] familiarized parametric b-MS, as an over simplification of both metric and b-MS. In 2016 Sedghi et. al. introduced the Sb-MS [35] as a sandwich of S-metric & b-Metric space wherein author concluded that every S-metric is an S_b -metric with $b = 1$. Following him N. Tas and N. Y. Ozgur (2016) innovatively added parameter t to gain Parametric S-Metric space. This structure has new properties due to parameter t .

Parametric S-metric (2016): [36]

Assume non-empty set $\mathfrak{P}$ and $b \geq 1$ be a given real number. A function $d: \mathfrak{P} \times \mathfrak{P} \times \mathfrak{P} \times (0, \infty) \rightarrow [0, \infty)$ is a function. dis called a parametric S-metric on $\mathfrak{P}$,

$$(i) \quad d(\zeta, \theta, \xi, t) = 0 \text{ iff } \zeta = \theta = \xi$$

$$(ii) \quad d(\zeta, \theta, \xi, t) \leq d(\zeta, \zeta, a, t) + d(\theta, \theta, a, t) + d(\xi, \xi, a, t) \text{ for all } \zeta, \theta, \xi, a \in \mathfrak{P} \text{ and } t > 0$$

Then the pair $(\mathfrak{P}, d)$ is called parametric S-MS.

Tas & Ozgur (2018) [37] enhanced their own idea and developed Parametric Sb-MS. Following the research works of Suzuki and

Branciari, Mani (2018) [38] invented a generalized C_{β}^{ψ} -rational contraction as the modifications of Rational and C-condition.

In Parametric Sb-MS Mani et al (2023) inserted a function to develop Extended Parametric Sb-Metric space [39].

Extended Parametric Sb-Metric space [39]:

Let P be a non-empty set and $\varrho: P^3 \rightarrow [1, \infty)$ be a positive real-valued function. Let function $d: P^3 \times (0, \infty) \rightarrow [0, \infty)$ such that for all $\zeta, \vartheta, \xi, \sigma \in \mathfrak{P}$ and $\lambda > 0$.

$$\begin{aligned} \text{(i)} \quad & d(\zeta, \vartheta, \xi, \lambda) = 0 \text{ iff } \zeta = \vartheta = \xi \\ \text{(ii)} \quad & d(\zeta, \vartheta, \xi, \lambda) \leq \\ & \varrho(\zeta, \vartheta, \xi) [d(\zeta, \zeta, \sigma, \lambda) + \\ & d(\vartheta, \vartheta, \sigma, \lambda) + d(\xi, \xi, \sigma, \lambda)] \end{aligned}$$

Resultant function d is along with $\mathfrak{P}$ forms pair $(\mathfrak{P}, d)$ Extended parametric Sb-MS.

CONCLUSION

This paper investigated theoretical deviations from classical Metric space, highlighting their mathematical properties and structural differences. It analyzed variations in key concepts like distance, continuity, and convergence, offering a detailed overview of their divergence from traditional metrics. The study enhances understanding of the flexibility and potential of generalized Metric space. It also establishes a foundation for further theoretical advancements. Future research could explore broader generalizations and their implications.

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Simplifying Diabetic Retinopathy Diagnosis with VGG-NIN: A Survey

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ABSTRACT

Retinopathy (DR) is a severe eye disorder that harms the retinal blood vessels and can lead to blindness over time. The present day diagnosis technique requires manual overview of colored images of the retina through medical experts, which may be each sluggish and liable to mistakes. To deal with these issues, pc vision methods have been used to automate DR detection. but, many existing strategies face issues with high computational necessities and inefficient characteristic extraction, main to demanding situations in appropriately classifying exceptional degrees of DR. This paper gives a brand new technique to classifying DR levels the use of fewer trainable parameters, making the training procedure faster and enhancing the model's accuracy. The VGG16 architecture, enhanced with a spatial pyramid pooling (SPP) layer and network-in-community (NiN) systems, bureaucracy the VGG-NiN model. This model can system DR photographs at numerous scales due to the ability of the SPP layer, at the same time as the NiN allows seize complicated capabilities, enhancing accuracy. The consequences show that the model plays higher than current methods in terms of each accuracy and computational performance.

KEYWORDS : CNN, VGG16, Image processing, Diabetic retinopathy, Deep learning, CNN.

INTRODUCTION

Diabetic retinopathy (DR), a common side effect of diabetes, can lead to blindness if not detected early. This paper focuses on using advanced deep learning techniques, particularly the VGG-NiN architecture, to identify and classify DR in retinal images. DR is a major cause of vision loss worldwide, especially among people with diabetes. Detecting eye problems beforehand is essential to avoid long- term vision impairment. Our goal is to leverage the power of deep learning to create a system that automatically detects diabetic retinopathy from retinal images, providing a faster and more accurate diagnosis method than traditional techniques.

The introduction covers the increasing prevalence of DR globally and highlights the stages of the disease, from early (non-proliferative DR) to more advanced stages (proliferative DR). It discusses the challenges in detecting the condition early, as many patients may not show symptoms until significant damage occurs. This emphasizes the need for better detection methods, where convolutional neural networks (CNNs) offer a promising solution.

RELATED WORK

This area audits current methods used for DR detection, focusing on their strengths and weaknesses.

Qummar et al. [9]: Profound Learning Gathering for Multi-Class DR Detection

Qummar et al. utilized an outfit of pretrained models, counting ResNet50, DenseNet169, InceptionV3, DenseNet121, and Exception, to realize an accuracy of 80.8% for multi-class classification of diabetic retinopathy stages. Whereas the outfit approach progressed by and large exactness, it too presented complexity, which made the show computationally costly and less interpretable.

Ghosh et al. [10]: CNN Demonstrate with MA and HE Detection

Ghosh et al. created a CNN show for identifying microaneurysms (MA) and hemorrhages (HE), two key pointers of diabetic retinopathy. Be that as it may, the show experienced challenges in precisely classifying early-stage DR (stages 1 and 2). These stages were frequently misclassified as arrange (negative course), reflecting the trouble in recognizing inconspicuous highlights in early

stages. The model's battle to recognize early stages limits its viable application, as early discovery is basic for anticipating infection progression.

Dutta et al. [11]: Assessment of Different Neural Systems for DR Classification

Dutta et al. presented three neural organize models: Nourish Forward Neural Arrange (FNN), Profound Neural Arrange (DNN), and Convolutional Neural Arrange (CNN). These models were tried on a dataset of diabetic retinopathy pictures, accomplishing a most extreme exactness of 0.89 on the preparing information. The preprocessing methods included calculating the cruel, middle, and standard deviation for normalization.

Gondal et al. [14]: CNN-Based Binary Classification of Diabetic Retinopathy (RDR)

Gondal et al. proposed a convolutional neural arrange (CNN) demonstrate particularly for the twofold classification of diabetic retinopathy (DR) stages. The show gathered the stages into two categories: 0/1 (non-referable DR) and 2/3/4 (referable DR). This choice was based on the trouble in recognizing the highlights of arrange 1 DR, such as microaneurysms and minor hemorrhages, which are frequently unobtrusive and challenging to classify with tall precision. The CNN demonstrate utilized a feebly directed learning approach for identifying referable diabetic retinopathy (RDR), pointing to decrease the require for nitty gritty manual explanation of retinal injuries, a common challenge within the therapeutic space.

Yang et al. [15]: Two-Stage DCNN for DR Classification

Yang et al. created a profound convolutional neural organize (DCNN) that utilized worldwide and nearby systems in a two-stage classification prepare. This demonstrate was utilized to recognize between non-diabetic (NDPR) and ordinary retinopathy pictures. The execution of the demonstrate was assessed utilizing the kappa score, which measures inter-rater assertion for subjective things.

García et al. [16]: CNN Architectures with VGGNet16 for DR Detection

García et al. tested with diverse CNN designs such as AlexNet and VGGNet16, centering essentially on differentiate change in retinal fundus pictures. VGGNet16 accomplished the best-reported comes about, with affectability, specificity, and precision of 0.54, 0.93, and 0.83, individually. In spite of accomplishing tall execution, the need of nitty gritty classification into person stages

restricted the clinical utility of this demonstrate for early discovery, where exact arranging is essential.

Takahashi et al. [17]: AI-Based Illness Arranging with Retinal Region Consideration

Takahashi et al. proposed an AI-based demonstrate that considered the retinal region for decision-making in DR organizing. The creators utilized a altered Davis arranging method, which made strides the model's decision-making prepare by centering on spatial highlights of the retina. The demonstrate illustrated a lower false-negative rate (FNR) compared to the untrue positive rate (FPR), which is especially critical in diminishing missed analyze.

PROPOSED WORK

In the proposed work, we introduce a novel approach that leverages the VGG-NiN (Network in Network) architecture for the detection and classification of diabetic retinopathy (DR) from retinal images. This architecture is designed to overcome limitations in traditional methods and offers improvements in performance, particularly in handling image features and the complex classification problem.

Dataset Description

The dataset used for this is sourced from Kaggle and is organized by EyePACS, consisting of 88,702 retinal images. Out of these, 35,126 images are labeled for diabetic retinopathy classification, divided into five distinct classes representing the severity of DR, ranging from no DR to proliferative DR.

- **Dataset Composition:** The images are labeled into five categories, each indicating different stages of DR.
- **Class Distribution:** For detailed class distribution, refer to Table 1 in the original paper.

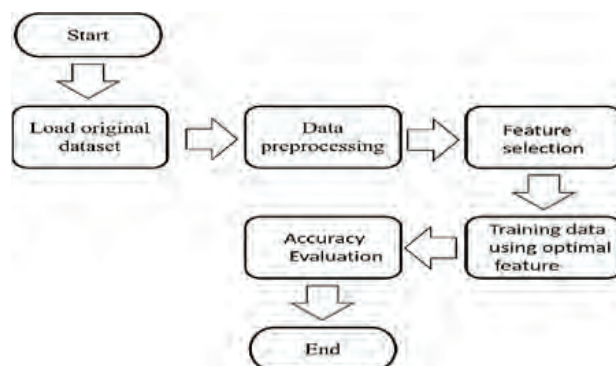


Fig. 1 : Preprocessing steps

Preprocessing Steps

To prepare the dataset for training, several preprocessing steps were applied to ensure uniformity and enhance model performance:

1. **Image Resizing:** All images were resized to a consistent size of 1349×1024 pixels, preserving the aspect ratio.
2. **Random Cropping:** Images were further cropped to a fixed size of 1024×1024 pixels for consistent input to the model.
3. **Dataset Splitting:** The dataset was divided into three subsets: Training Set: 64% of the dataset Validation Set: 20% of the dataset Test Set: 16% of the dataset
4. **Adaptive Learning Rate:** An adaptive learning rate starting from 0.01 to 0.0001 was used to prevent overfitting during training.
5. **Image Augmentation:** Keras' ImageDataGenerator was utilized for data augmentation techniques like rescaling, shearing, zooming, and flipping to enhance the diversity of the dataset and improve model generalization.

The VGG-NiN Model

The core of the proposed system is the VGG-NiN model, which integrates components from VGG16, Spatial Pyramid Pooling (SPP), and Network in Network (NiN).

1. **VGG16 Handling:** The base model, VGG16, accepts input images of size 224×224 pixels. The images are passed through several convolutional layers, each extracting progressively more abstract features from the input.
2. **Spatial Pyramid Pooling (SPP):** A key feature of this system is the addition of an SPP layer between the final convolutional layer and the fully connected layers. The SPP layer generates a fixed-size output vector, regardless of the size of the input image, making it adaptable to variable image sizes without losing spatial information.
3. **Network in Network (NiN):** On top of the SPP layer, we introduce NiN, which utilizes `mlpconv` layers (multi-layer perceptron's) for better feature encoding. Unlike traditional CNNs that use linear filters, NiN applies small neural networks to patches of the image, increasing the depth of feature abstraction. This helps

in capturing more complex patterns in the data that may not be easily detected by a simple convolutional network.

4. **Parametric ReLU (PReLU):** The activation function used in the NiN layers is PReLU, which is an extension of the traditional ReLU (Rectified Linear Unit) function. PReLU learns the activation parameters during training, allowing the model to adapt the activation function to the data, potentially reducing overfitting and improving convergence.
5. **Classification with Softmax:** For final classification, a softmax activation function is used, which outputs probabilities for each of the five classes in the diabetic retinopathy classification task.
6. **Loss Function & Optimizer:** The model is trained using categorical cross-entropy as the loss function, and Stochastic Gradient Descent (SGD) as the optimizer, which adjusts the weights of the model to minimize the classification error.

This comprehensive architecture ensures that the model can effectively handle both the complexity of diabetic retinopathy detection and the variability in image sizes and quality, making it a robust solution for medical image analysis.

Initialization and Hyperparameters

Model Initialization: VGG network's convolutional layers solidified utilizing exchange learning; NiN initialized through the Xavier method. **Hyperparameters:** : Allude to Table 3 in the paper for diverse hyperparameter values.

Learning Rate Adaptation: Versatile learning rate with adjustments if approval loss stagnates over five continuous iterations.

This proposed technique amalgamates VGG16, SPP, and NiN, leveraging exchange learning, versatile learning rates, and modern information preprocessing to address the challenge of diabetic retinopathy location utilizing profound learning techniques.

Table 1: Hyper-parameters

Batch size	8
Initial learning rate	0.01
Momentum	0.9
Minimum learning rate	0.000,1
Number of epoch	50

SYSTEM STRUCTURE

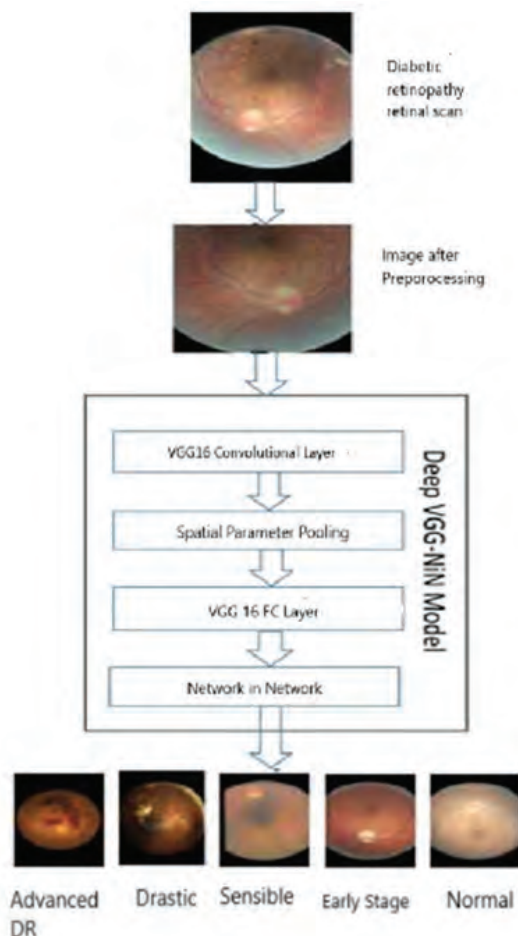


Fig..2 Basic Structure

In architecture diagram the first step involves a Retinal Scan of the input image after that preprocessing of image is done in terms of resolution. The preprocessed image is forwarded to Deep VGG-NiN Model and the model performs processing on the input image and the results are generated by classifying different stages of DR.

VGG-16 architecture

The VGG-16 is an elucidation of the well known convolutional neural network called VGG-Net. It takes as input a color image of size 224×224 px and classifies it into one of the 1000 classes. It subsequently returns a vector of measure 1000, which contains the probabilities of having a place to each of the classes. Each convolutional layer uses color filters of size 3×3 px, moved with a step of 1 pixel. The zero-padding is 1 pixel so that the input volumes have the same spatial scope.

Below is a general flowchart for the detection of diabetic retinopathy (DR) outlines the key stages involved in processing retinal images and classifying them based on the severity of DR.

Input Retinal Image

Purpose: The process begins with capturing the retinal images, either from a dataset (such as Kaggle's EyePACS) or directly from a retinal fundus camera. Images are generally in RGB format and vary in size.

Preprocessing

Image Resizing: The images are resized to a uniform dimension (e.g., 1024×1024 pixels) to ensure consistency when fed into the model.

Image Enhancement: This step may involve:

Contrast Enhancement: Improving image clarity to make features like blood vessels and lesions more visible.

Noise Reduction: Reducing noise to prevent the model from being distracted by irrelevant details.

Image Augmentation: Techniques such as flipping, zooming, and rotating the images are used to artificially increase the size of the dataset and improve model generalization.

Segmentation and ROI Extraction (Optional)

Purpose: This optional step involves identifying and focusing on specific regions of interest (ROIs) in the retina, such as the optic disc or lesions. Segmentation techniques are applied to isolate important features that could indicate DR, like hemorrhages, microaneurysms, or exudates.

Feature Extraction

Pre-trained Model (e.g., VGG16): A pre-trained deep learning model, like VGG16, is used to extract features from the retinal image. These features include shapes, textures, and patterns that may indicate abnormalities.

Advanced Techniques (e.g., SPP and NiN): Layers like Spatial Pyramid Pooling (SPP) and Network in Network (NiN) are added to enhance the feature extraction process by making the system more robust to varying image sizes and by improving high-level feature representation.

Classification

Deep Learning Model: The extracted features are fed into the classification model (VGG-NiN in the proposed system) to determine the severity of diabetic retinopathy.

The model predicts one of the five DR classes: No DR, Early Stage, Sensible, Drastic, Advanced DR.

Activation and Loss Functions: The model uses softmax as the activation function for output, and categorical cross-entropy as the loss function to minimize classification errors.

Output Prediction

DR Class: The final output is the predicted class of diabetic retinopathy (e.g., mild, severe). This classification helps in determining the next course of action, such as further medical consultation or treatment.

Confidence Score: The model may also provide a confidence score along with the prediction, indicating how certain the model is about its classification.

Post-Processing and Reporting

Medical Report Generation: The system can generate a report that summarizes the findings and predictions, which can be reviewed by medical professionals for diagnosis and treatment planning.

Visualization (Optional): In some systems, heatmaps or feature maps may be generated to show which parts of the retina influenced the prediction.

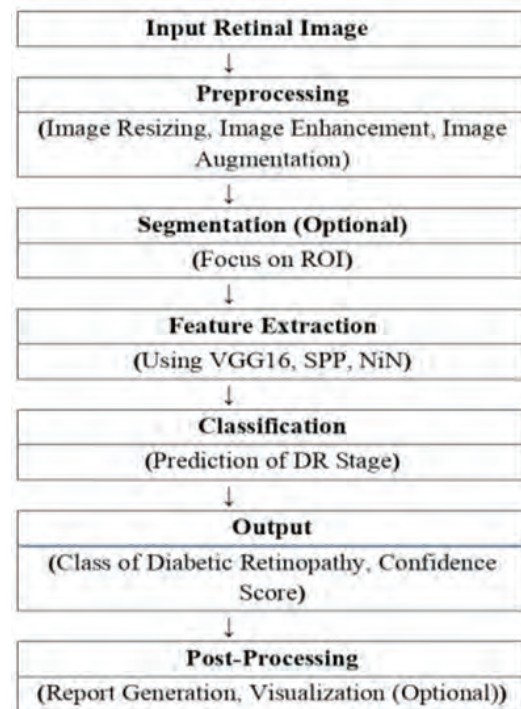


Fig. 2: Visual Flow (Summary)

Table 2 : Summary Of Reviewed Diabetic Retinopathy

Paper Title	Year	Author(s)	Methodology/ Approach Used	Dataset Used	Performance Measure	Accuracy Achieved
Deep learning ensemble approach for diabetic retinopathy detection	2019	Qummar et al. [9]	Pretrained ensemble models (ResNet50, DenseNet121, Xception) for multi class DR detection.	Kaggle Dataset	Multi-class Classification Accuracy	80.8%
Automatic detection and classification of diabetic retinopathy stages using CNN	2017	Ghosh et al. [10]	Used CNN to detect DR stages. MA and HE detection struggled with early stage classification (stages 1 and 2).	Private Dataset	Class Distribution Accuracy	Not specified
Classification of diabetic retinopathy images by using deep learning models	2018	Dutta et al. [11]	Compared Feedforward NN, Deep NN, and CNN. Preprocessed images with mean, median, and standard deviation filters.	Private Dataset	Training Accuracy	0.89
Weakly supervised localization of diabetic retinopathy lesions in retinal fundus images	2017	Gondal et al. [14]	Proposed CNN for binary classification of DR stages (Referable DR - RDR). Grouped stages 0/1 and 2/3/4.	Private Dataset	Sensitivity, Specificity	Not specified
Lesion detection and grading of diabetic retinopathy via two-stage DCNNs	2017	Yang et al. [15]	Two-stage Deep CNN with global and local networks for grading non-diabetic and normal cases.	Private Dataset	Kappa Score	Not specified

Detection of diabetic retinopathy based on CNNs	2017	García et al. [16]	Experimented with AlexNet and VGG16 for classification. Improved contrast enhancement in images.	Private Dataset	Sensitivity: 0.54, Specificity: 0.93	0.83
Classifying diabetic retinopathy using deep learning architecture	2016	Kathirvel et al. [23]	Applied deep CNN architecture for spatial feature analysis in fundus images.	DRIVE Dataset	Sensitivity, Specificity	94%

CONCLUSION

In conclusion, our study presents a novel approach for diabetic retinopathy stage classification using the VGG-NIN deep learning architecture. The reviewed model demonstrates superior performance compared to existing methods, offering potential benefits for early detection and management of diabetic retinopathy. Continued research and refinement of the model are essential to its practical applicability in clinical settings.

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Explore the Suicidal Notes to Understand the Negation Behavior Behind It: Through Multi-labeled Sentiment Analysis

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ABSTRACT

Understanding human psychology is a challenging task and framing a structured machine learning approach to evaluate it is more hard. According to WHO (World Health Organization) 720 000 suicidal cases happened every year, to reduce this number, one need to find causes behind these suicide attempts. With the help of advanced Natural Language Processing (NLP), Machine Learning (ML), and Deep Learning (DL) techniques, our work try to identify fine-grained sentiments from the suicidal notes, aiming to meticulously analyze human behavioral patterns in textual content. In this way this Project works on multi-labeled Sentiment Analysis, the model delves into the subtleties of human expression, contributing detailed insights into the complex emotional landscape within written contexts. The collaborative integration of NLP, ML, and DL creates a robust framework capable of capturing and categorizing multiple sentiments at a granular level (sad, fearful and angry). This interdisciplinary research holds the potential to advance sentiment analysis methodologies, providing a precise interpretation of human behavioral patterns in written communication, to enhance applications in diverse fields such as market research, customer feedback analysis, social media monitoring, and, notably, in the identification and understanding of mental disorders through textual indicators. From Machine Learning SVM, Decision Tree, Naïve-Bayes have been tested with Tf-Idf vectorization and with the help of Bi-LSTM technique a hybrid Model has been developed to handle the defined problem.

KEYWORDS : *Natural language processing, TF-IDF, SVM, Decision tree, Naive bayes, Bi-LSTM, Machine learning, Fine grained sentiment analysis.*

INTRODUCTION

In the contemporary landscape of digital communication, deciphering the intricacies of human sentiment embedded within textual content has emerged as a paramount pursuit. Conventional sentiment analysis methodologies often lack the depth and granularity necessary to capture the multifaceted nature of human emotions, thereby presenting a significant challenge in understanding human behavioral patterns accurately. However, with the advent of advanced Natural Language Processing (NLP), Machine Learning (ML), and Deep Learning (DL) [9,10] techniques, there exists a profound opportunity to propel sentiment analysis into new realms of sophistication and insight. The focal point

of this research endeavor lies in the advancement of multi-class [8] sentiment analysis—an exploration that transcends binary classifications to embrace the nuanced spectrum of human emotions. Through a comprehensive examination of textual data, this study endeavors to conduct a deep dive into human behavioral patterns, unraveling the complex tapestry of emotions woven into written communication.

With a methodological approach that embraces Machine Learning techniques including Support Vector Machines (SVM), Decision Trees, and Naïve-Bayes, this research endeavors to test and refine various models to handle the complexities inherent in multi-class sentiment analysis. Data collection will be conducted in paragraph format, facilitating

a holistic analysis of textual content and affording insights into the intricate interplay of human emotions and behaviors. In essence, this collaborative endeavor represents a concerted effort to advance the frontiers of sentiment analysis, charting a course towards a deeper understanding of human behavioral patterns in the digital age.

LITERATURE SURVEY

We did a literature review to demonstrate the significance of sentiment analysis in constructing advanced models to capture complex human emotions. The survey discusses binary sentiment analysis and Bi-LSTM techniques.

Table 1: Literature Review on Binary Sentiment Analysis

Sr. No	Paper Title	Review on Techniques details	Implementation
1	Toward Machine Learning Based Binary Sentiment Classification of Movie Reviews for Resource Restraint Language (RRL)—Hind [1]	Stacked Ensemble-Based Architecture (SEBA)	The study presents a stacked ensemble-based architecture (SEBA) for sentiment classification on the Hindi Language Movie Review dataset, achieving an accuracy of 80.8% and an F1-score of 80.7%.
2	An Extensive study of Sentiment Analysis tools and Binary Classification of tweets using Rapid Miner [2]	Support Vector Machine (SVM) Decision Trees Naive Bayes	Vishal Vyas et al.[2] used RapidMiner for sentiment analysis on Twitter data, using various machine learning methods. SVM performed better, achieving 82.61% precision, 40.23% recall, and 79.08% accuracy.
3	Sentiment Analysis Using Machine Learning Algorithms [3]	Comparison of Multinomial Naive Bayes, Bernoulli Naive Bayes, Logistic Regression, and SVM for sentiment classification.	The work uses machine learning and text mining techniques on the NLTK dataset to create a sentiment analysis model that classifies tweets as positive or negative, hence boosting precision. Future work will concentrate on managing complex sentiments and introducing additional sentiment labels.

Table 2: Literature Review on Bilstm

Sr. No	Paper Title	Review on Techniques details	Implementation
1	A computationally efficient BiLSTM based approach for the binary sentiment classification[4]	BiLSTM	The BiLSTM model improves contextual awareness by assessing past and future information. It also contains a global maximum pooling layer for feature extraction. To avoid overfitting, its multilayer architecture necessitates precise hyperparameter tweaking and dropout regularization.
2	Convolutional Recurrent Deep Learning Model for Sentence Classification.	LSTM+CNN, Back-propagation Through Time	The model uses CNNs for feature learning and LSTMs for context understanding, which improves classification while raising training time, resource demands, and overfitting hazards on smaller datasets.[5]
3	Children Sentiment Analysis from Texts by Using Weight Updated Tuned with Random Forest Classification	LSTM, Random Forest, SVD, PCA	The hybrid framework improves accuracy by combining deep learning and ensemble approaches, while reducing feature redundancy with PCA and SVD.[6]

Binary sentiment analysis is efficient but limiting, whereas LSTM models capture nuanced emotions well. Multiclass analysis provides a more comprehensive insight, particularly for delicate themes such as suicidal thoughts[7]. Combining classical approaches with LSTM increases sentiment analysis accuracy and behavioral insights.

RELATION AND MAPPING OF SUICIDAL CAUSES FROM BEHAVIORS AND SENTIMENTS

Understanding the connection between emotions, behaviors, and suicidal ideation is vital for identifying root causes. Behaviors like aggression, avoidance, and addiction, driven by emotions such as anger, fear, or despair, often stem from unresolved trauma, anxiety, or hopelessness. Mapping these patterns is essential for addressing psychological triggers and developing effective interventions.

Table 3: Relation of Sentiments-Behavior and It's Suicidal Causes

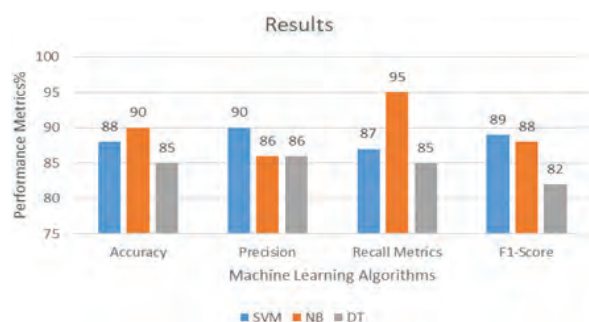
Sr. No	Sentiments	Behavior	Suicidal Causes
1	Angry	Distrust, Bitterness, Feelings of Betrayal, Emotional Turmoil	Betrayed Trust, Breakup
2	Sad	Despair, Withdrawal, Lack of Motivation, Emotional Numbness, Vengefulness, Distrust	Hopelessness, Betrayal Trauma
3	Fearful	Defiance, Aggression, Resentment, Withdrawal, Flashbacks	Social Rejection, Unresolved Trauma

Table 4 illustrates the relationship between sentiments, behaviors, and their corresponding suicidal causes, emphasizing how emotional states like anger, sadness, and fear manifest through distinct behaviors and contribute to suicidal ideation.

MACHINE LEARNING APPROACH

Bag of Words (BoW)

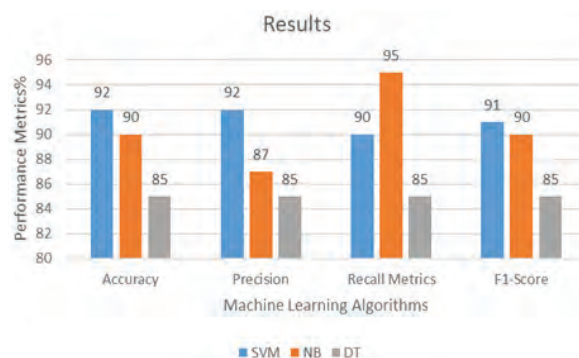
Bag of Words (BoW) converts text into word frequency vectors, useful for sentiment and behavioral analysis by highlighting frequent terms linked to emotions or actions. However, it treats all words equally, reducing accuracy in capturing nuanced patterns.

**Fig. 1 Results of Bag of Words**

TF-IDF Vectorization

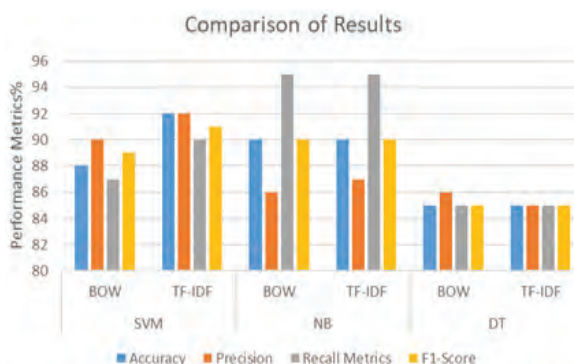
TF-IDF improves on BoW by weighting terms based on relevance, downplaying common words while emphasizing

unique ones. It enhances sentiment and behavioral analysis by highlighting key phrases and improving accuracy through context detection.

**Fig. 2 Results of TF-IDF**

Preference for TF-IDF over bag of words

TF-IDF surpasses Bag of Words by efficiently weighing key terms, enhancing sentiment analysis accuracy. Its focus on meaningful concepts enables precise detection of behavioral patterns and emotional drivers.

**Fig. 3 Comparison about BOW and TF IDF**

TF-IDF surpasses BoW in all classifiers, obtaining 92% accuracy and precision with SVM against 88% with BoW. Its capacity to weigh words based on their significance aids in the identification of emotional nuances. TF-IDF also performs well alongside Naive Bayes and Decision Trees, making it the more dependable option for fine-grained sentiment analysis.[11,13]

TF-IDF Implementation and Results

In our research, the Term Frequency-Inverse Document Frequency (TF-IDF) technique was used to assess the relevance of terms in a dataset containing 3,16,000 suicidal and non-suicidal notes.

Table 4 Number of Each Labeled Data in Dataset

Total Entries	Suicidal	Non-Suicidal
3,16,000	1,16,000	1,15,000

The TF-IDF technique weights phrases based on their frequency in individual documents and across the collection, emphasizing terms specific to suicide notes. We investigated the predominance and significance of important phrases in the dataset by identifying the top 50, 100, 150, 200, and 500 terms based on their TF-IDF scores.

To fine-tune our research, we used threshold values of 1, 25, and 50 to filter word occurrences, attempting to discover key terms while reducing noise. At a threshold of 50, we discovered 19,150 relevant terms, 25,000 at 25 and 30,000 at 1. To focus the investigation on specific phrases, we divided the terms into 15K unigrams, 10K bigrams, and 5K trigrams.

Table 5 Showing Number of Words from Top 40k N-Grams after Applying Threshold

Words	Threshold		
	1	25	50
Unigrams (15K)	15,000	10,296	7,112
Bigrams (10K)	10,000	10,000	10,000
Trigrams (5K)	5,000	5,000	2,369
Total	30,000	25,296	19,554

The results of these thresholds and categories paint a clearer picture of the lexicon connected with suicidal notes, allowing for further investigation of their relevance in understanding suicidal conduct.

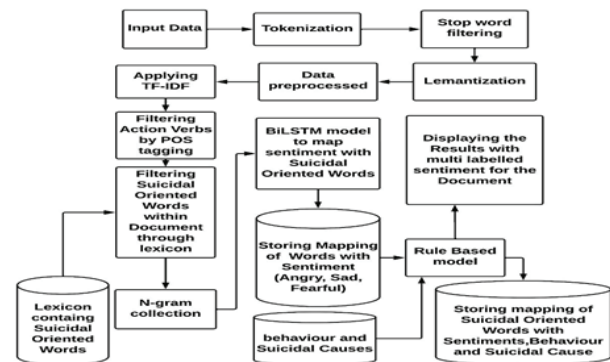
FINDING SENTIMENTS PREDICTING BEHAVIOUR AND SUICIDAL CAUSE BASED ON WORDS

Using a online lexical dataset with 29 attitude shades, we classified 262 suicide-related words into three categories: angry, sad, and fearful. This approach helped us connect emotions to suicide conduct, allowing us to predict the underlying causes. By evaluating the emotions associated with each word, particularly anger, grief, and fear, we discovered behavioral patterns critical for suicide prevention and intervention.[14]

Fig. 4 Suicide oriented words with Sentiments Mapped,Predicted Behavior and Suicidal Cause

The mapping identified emotional pathways that contribute to suicidal conduct. Anger-driven notes frequently reflect dissatisfaction or unfairness, implying rash actions. Melancholy notes expressed pessimism, loneliness, or grief, implying emotional detachment. Fear-based notes highlighted fears, future concerns, or abandonment, indicating insecurity. Understanding these emotions aids in predicting the reasons of suicide ideation and related behavioural responses.

PROPOSED SYSTEM ARCHITECTURE

**Fig. 5 System Architecture**

In this study, we employed a hybrid technique that combined Rule-Based Sentiment Analysis and BiLSTM to better comprehend the emotional patterns associated with suicidal thoughts and behaviors.

Rule based Approach

The proposed rule-based sentiment analysis system employs many strategies to identify suicide-oriented emotions and potential causes of suicidal behavior.

- Text Preprocessing: Tokenization and stop word removal prioritize significant content.
- Numerical Representation: TF-IDF and n-grams identify essential concepts and phrases.

- Synonym Expansion: WordNet contains synonyms for many terms.
- POS Tagging: Identifies action verbs for determining purpose and conduct.
- Rule-Based Sentiment Analysis: Classifies words as emotional states such as anger, sadness, and fear.
- Behavioral and Cause Prediction: Examines sentiment patterns to identify potential behavioral reasons.

BiLSTM

In our study, we used a BiLSTM model that blends rule-based approaches and deep learning. We began by processing a dataset of 116,000 suicide notes with the rule-based model, which produced text, sentiment, behavioral tendencies, and suicidal reason data. Using the text, sentiment, and behavior columns, we trained the BiLSTM model to predict sentiments.

Word	Behavior	Suicidal Cause
abandon	Loneliness	Feeling of rejection
ache	Emotional Pain	Chronic emotional distress
actuate	Impulsiveness	Sudden decisions under stress
agony	Deep Suffering	Physical or emotional trauma
alone	Isolation	Social withdrawal
alternate	Confusion	Uncertainty about life choices
anguish	Intense Grief	Loss of a loved one
annoyance	Frustration	Ongoing unresolved conflicts
anxious	Anxiety	Inability to cope with stress

Fig. 6 Word-Behavior-Suicidal Cause

Using Keras and TensorFlow, we develop a bidirectional long short-term memory (BiLSTM) model for sentiment analysis. After importing the required libraries and loading the dataset, we clean the data by deleting rows with empty sentiment values. The text is tokenized, padded to maintain a consistent length, and sentiment labels are one-hot encoded. We also use pre-trained word embeddings with the GloVe matrix to boost the model's semantic understanding.[12] This dual strategy combines BiLSTM predictive capacity with rule-based approaches to produce more accurate and reliable suicide prevention forecasts.

```
# Load the 200d GloVe file
glove_file = 'glove.6B.200d.txt'

embeddings_index = load_glove_embeddings(glove_file)
print(f"Loaded {len(embeddings_index)} word vectors.")

Loaded 400000 word vectors.
```

Fig. 7 Glove Vectors

The BiLSTM model consists of an embedding layer, a bidirectional LSTM layer, and dense classification layers. It is built with categorical cross-entropy loss and optimized with Adam. After training for a predetermined number of epochs, the model's performance is assessed using accuracy metrics.

```
[ ] # Evaluate the model
loss, accuracy = model.evaluate(padded_sequences, labels, verbose=1)
print(f"Accuracy: {accuracy * 100:.2f}%")
```

3427/3427 — 40s 12ms/step - accuracy: 0.9899 - loss: 0.0368
Accuracy: 98.43%

Fig. 8 Performance Metrics

The trained model is saved as `bilstm_senti_model.keras`, which retains the architecture, weights, and optimizer for future use. Suicidal-oriented terms are associated with behaviors and emotions, which aid in mapping suicide causes. The research culminates with a model evaluation to determine the efficacy of the approaches utilized.

CONCLUSION

This research harnesses advanced NLP, ML, and DL techniques to explore fine-grained sentiment analysis, offering detailed insights into human emotions and behaviors within textual content. By transcending binary classifications, it delves into multi-class sentiment analysis, uncovering the nuanced spectrum of emotions and their interplay. Through the integration of methodologies like SVM, Decision Trees, and Naïve Bayes, the study refines approaches to capture and categorize sentiments at a granular level. This interdisciplinary effort lays the foundation for applications in fields such as market research, social media monitoring, and mental health analysis, paving the way for deeper understanding and innovative advancements in sentiment analysis.

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Review paper on Food Images Recognition and Calorie Estimation

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ABSTRACT

In recent years, it has become evident that the world is grappling with a burgeoning public health crisis characterized by escalating rates of conditions like obesity, diabetes, and a spectrum of related metabolic and cardiovascular disorders. The key driver of these health problems lies in the profound shifts in dietary patterns. Dietary habits have shifted towards higher consumption of energy- dense, processed foods, and beverages, resulting in excessive calorie intake, often accompanied by inadequate nutrient content. Addressing these challenges requires a multi-pronged approach that encompasses healthcare interventions. Strategies must focus on promoting healthier lifestyles, facilitating access to nutritious foods, and increasing awareness about the risks associated with these conditions. With the mounting global burden of diet-related diseases and health conditions, dietary assessment has emerged as an indispensable tool for both researchers and healthcare professionals. It enables the collection of vital data regarding individuals' food consumption, nutrient intake, and dietary patterns, offering a detailed picture of dietary habits. Every individual has unique dietary requirements and goals, making one-size-fits-all dietary recommendations inadequate. Machine learning models can analyze an individual's dietary data, preferences, and health markers to deliver tailored nutritional guidance, promoting better adherence and improved health outcomes. In this paper, we provide a comprehensive review of various methodologies employed for food recognition and calorie estimation.

KEYWORDS : *Image analysis, Calorie estimation, Dietary assessment.*

INTRODUCTION

Object Detection

Object Detection is one of the crucial tasks in computer vision for detecting the object in the real time scenario and identifying the object in an image. Various algorithm like R- CNN (Region with Convolutional Neural Network), SSD (Single Shot Detector), YOLO (You Only Look Once), etc. are performed in object detection. R-CNN is a two-stage approach where the object detection and recognition performs in two different techniques. It is a special type of CNN where the set of bounding boxes classify and detect each object. It uses region for detecting different object and these regions are

generated at multiple scales and aspect ratios. Over the several improvements on the basic RCNN architecture resulting in variation like Fast RCNN, Faster RCNN, Mask RCNN to optimize the speed, accuracy, performance of the model. SSD is one stage approach the object detection and recognition performed in single technique and it is done simultaneously. Because of single convolutional neural network implementation SSD is more efficient than other CNN methods. It has a light architecture for lite mobile application as it uses less parameter in comparison. YOLO is also a fast one stage approach. Its architecture is similar to FCNN (Fully Convolutional Neural Network). YOLO treats the detection task as a regression problem and uses a single neural network to predict the bounding boxes and

the corresponding classes. As YOLO can detect multiple items in a single image which helps in detecting Indian Food items in a single image.

Dietary Assessment

Food is the key of human's body. So, a diet plan always needs to take into consideration the total number of calories to be consumed to maintain a fit and healthy life. But, in most cases, unfortunately people face difficulties in estimating and measuring the amount of food intake due to the mainly lack of nutritional information, which includes manual process of writing down this information, and other reasons. As such, it will be useful if there is a system to keep track and maintain the calorie intake. Hence accurate prediction of food calorie is equally important in such cases.

This can be done by first recognizing the food images using various algorithms like YOLO, CNN, etc. and the estimating the calorie content present in the food. Some of the methods used for nutrition estimation are 1) combining the food nutrition analysis + EDA dataset which contains different types of foods and the presence of different nutrients in it. The food and nutrients are present as a key value pair separated by colon, once the food is recognized the information about the the nutrients present in the food is extracted from the above dataset.

2) Another method which is generally used for calorie estimation is using volume estimation to measure the mass of food portion. Volume of the food is been calculated using total area of food in the image with respect to the finger i.e. the calibration object is used. Then by approximating these detected items to a geometric shapes like sphere, cylinder, rectangle, etc. the volume of food item is calculated. Food density is been obtained from readily available datasets.

Estimated weight of the food= Actual Density x Estimated Volume
Calories are then been calculated using the formula
Estimated Calories = (Estimated Weight x calories per 100gm) /100

LITERATURE REVIEW

In this research paper, the food object is detected in real time scenes and localize within the image to connect the application framework. The dataset used in this paper are collection from various online resources and manually labelled to each data using labelImg annotation tool. This dataset contains 60 classes and 70 images in each classes. Their model uses convolution network architecture where

the Single shot Detector is paired with Inceptionv2 and Mobilenetv2 to compare the most efficient approach of object detection. They work upon 20% of data for evaluation and the training and testing were randomly split. As the train to test ratio is 8:2 the TFRecord is accessed by tensorflow to use excess time in parsing data. Mean Accuracy Precision(mAP) of Inceptionv2 and Mobilenetv2 are 0.738 and 0.59 respectively. Other than mAP metrices, Classification Loss, recall, Localization Loss, etc. was calculated and thus found out that Single shot Detector paired with Inceptionv2 is more efficient model. Thus comprehending the model practically can estimate the accuracy of 97.6%. [1]

In this research paper, the dataset used for training this model is of two varieties including western foods, called Food-101, which was posed on Kaggle and another dataset containing Chinese Foods, called VireoFood-172 dataset. After labelling images using LabelImg and data cleaning process, comes the SSD (Single Shot Multibox Detector) algorithm implementation. The images passing through it's CNN gives a feature map, which then proceeds with generating default boxes on each pixel of feature map. Following this, the default bounding box that is paired to the ground truth box is taken positive, and the default bounding box that is not paired to the ground truth box is taken negative. Finally, all the generated default boxes are collected and non-maximum suppression algorithm is used to output the default box with the best matching effect. Lastly confidence and location loss is evaluated. A discrepancy is found at first, as the number of steps increases, the recognition accuracy will gradually increase, but after a certain number of steps, the recognition accuracy will fluctuate, it's because SSD is found to be giving less accuracy when dealing with small object detection and classification confusion with more iterations when it comes to dealing with factors like texture, color, etc. [2]

The paper "Food Recognition And Calorie Estimation Using Image Processing" presents a methodology for automatically recognizing and estimating the calorie content of food items from images. The algorithm follows a multi- step process: first, it uses image processing techniques such as segmentation and feature extraction to identify and isolate food items within the image. Then, a deep learning-based classification model i.e Convolutional Neural Networks(CNN) is employed to recognize the specific type of food. Next, the algorithm utilizes a food composition database to estimate the calorie content based on the recognized food item. To train and evaluate the

model, a large dataset i.e “Food 101” is used where there are 101 categories of food items , containing various types and serving sizes, is used, ensuring robust performance. This approach offers a way to track dietary intake by detecting single food item and weight of food item is given as input and based on the standard calorie value the accurate calorie value of the food item is calculated by machine learning techniques. [3]

This research paper covers Dietary assessment using food image object detection and classification using YOLOv4 algorithm. The dataset comprises of food images from Kaggle datasets and also a custom dataset created by the team members labelled using labellmg. This dataset consists of images belonging to different classes such as Apple, Banana, Orange, Pizza, etc. Yolo algorithm is shown working with three techniques which are, Residual block, Boundary Box regression and Intersection over union. YOLO can be applicable to multiple objects in a single image and able to predict multiple bounding boxes and class probabilities for those boxes. After the food item is identified, next comes Image segmentation, which includes resizing of original image, converting BGR to grey scale, etc. Lastly Calorie Estimation is done, where in they calculate volume of food items by approximating it to a geometric shape like sphere, cylinder, etc. Once they get the volume, the mass of the food item is calculated using the standard value of density. The amount of calories is calculated using the values of the volume and mass of the food item, which gives an accuracy of 83%. Further work can be done in order to increase the accuracy of the system and more classes can be included so that the system is capable of estimating calories for a variety of food item. [4]

The paper “Calorimeter: Food Calorie Estimation using Machine Learning” proposes a system for estimating the calorie content of food using machine learning. The system takes two images of the food, one from the front and one from the top, as input. It then uses GrabCut algorithms to detect the different food items in the images, estimate their portion sizes, and calculate the total calorie content. The system uses a Faster R-CNN Inception-v2 model to detect the food items in the images. Once the food items have been detected, the system uses a K-nearest neighbors (KNN) algorithm to estimate their portion sizes. The KNN algorithm works by finding the K most similar food items in a database of food items with known portion sizes. The average portion size of the K most similar food items is then used as the estimated portion size of the food item

in the image, then the system calculates the total calorie content by multiplying the portion size of each food item by its calorie content per gram. The calorie content per gram of each food item is obtained from a database of food items with known calorie content. The system was evaluated on a dataset of over 100,000 food images. The system is accurate way to estimate the calorie content of food using machine learning. [5]

In the research paper “Food Nutrition and Calories Analysis using Yolo” a user friendly interface is created which displays the Nutrition and calorie content of the food that user is consuming Food101 dataset was used for image recognition and classification Yolo algorithm was used for real time feature extraction .Initially the images were cut into 13x13 grids and then positioned to th midpoint to form a box and then image was reduced to 416x416 irrespective of the input sizes and training is carried out and food images are been classified .For calorie estimation food Nutrition analysis and EDA dataset were combined and a csv file was created in which the food and it’s concerned nutrients are present .Once the food is recognized by the model the information about the nutrients present in the food was extracted from the .csv file. Their model was able to achieve an accuracy of 92.37 % which can further be improved by using a large number of images. [6]

In the research paper “Calorie Estimation of Food and Beverages using Deep Learning” proposes an image based calorie estimation system that used deep learning to identify and estimate the calorie content of food items. The system uses CNN to extract features from the input image .15 different categories of food images were considered and the images were scaled from there original 100×100 proportions to 224×224 and were given as input to CNN model for learning. For calorie estimation, plate was considered as standard object and pixel per square inch was calculated. Their model was able to achieve accuracy of 78.7% for identification and 93.29% for calorie estimation. [8]

In this research paper, Recognizing Indian food in single food comes with three challenges: 1) Lack of annotated food dataset 2) Non distinct boundaries between dishes 3) High Intra class variation. These challenges are being resolve by providing makesense.ai tool for annotation of Indian food in IndianFood10 Dataset and using transfer learning with YOLOv4 object detector model for Indian food. They also used Python’s Selenium Library to

scrape Instagram post's URL for every hashtag and to download those images Python's Request library is used. Implementing the version 4 of YOLO algorithm over this dataset and along with an Intersection Over Union(IoU) threshold value of 0.5, they could achieve Mean Accuracy Precision(mAP) score 91.76% and F1 score 0.90 for object detection. [7]

METHODOLOGY

To build a dietary assessment model, a dataset of variety of food images is collected, in this case, "IndianFood20" dataset [10] is used which includes a diverse set of Indian food items. Then data preprocessing is performed to crop and resize the images to ensure a consistent size and aspect ratio. An annotation tool like "Labellmg" is utilized, to label the images in the dataset which enables the model to train, automate tasks and improve decision-making. Here the algorithm chosen is YOLO (You Only Look Once) algorithm as the deep learning model for object detection. YOLO is well-suited for real-time object detection tasks.

The following techniques within the YOLO framework can be implemented:

- **Bounding Box Regression:** Train the model to predict accurate bounding boxes around the food items.
- **Feature Extraction for Classification:** Extract features from the detected objects to classify them into specific food categories.
- **Model Training:** Split the labelled dataset into training and validation sets. Train the YOLO model on the training set using appropriate loss functions and optimization techniques.
- **Model Evaluation:** Calculate metrics such as F1 score and Mean Average Precision (mAP) to assess the model's accuracy and precision in detecting and classifying food items.
- **Image Segmentation:** Implement image segmentation techniques to segment the detected food items from the background.

After the mentioned techniques are performed, the next phase of the model is to estimate the calorie using a reference table of nutrition facts which will be built based on the data from USDA National Nutrient Database (NNDB) [9], it contains nutritional facts about 8618 basic foods including all the food items in our datasets and then the amount of nutritional ingredients is calculated for the

food items captured by users, by mapping the detected food to the reference table.

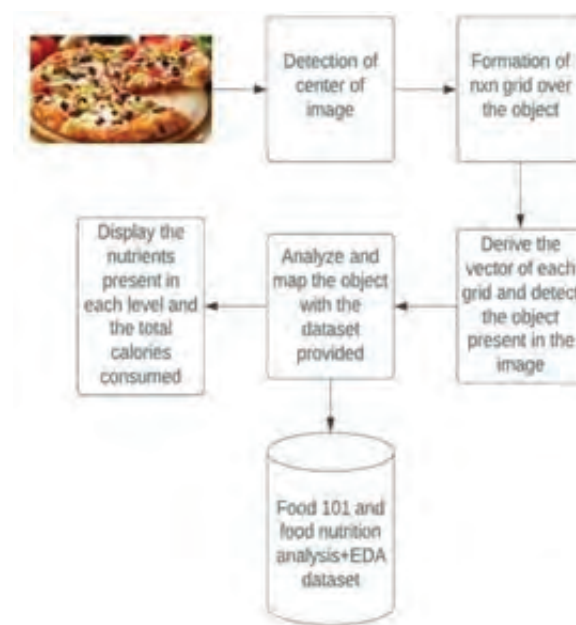


Fig. 1: Architecture

Table 1: USDA dataset for calorie estimation

Food	Measure	Grams	Calories	Protein	Fat	Sat.Fat	Fiber	Carbs	Category
Cows' milk	1 qt.	976	660	32	40	36	0	48	Dairy products
Milk skim	1 qt.	984	360	36	t	t	0	52	Dairy products
Eggs raw	2	100	150	12	12	10	0	0	Dairy products
Eggs Scram	2	128	220	13	16	14	0	1	Dairy products
Yolks	2	34	120	6	10	8	0	0	Fats, Oils, Shortenings
Butter	1T.	14	100	t	11	10	0	0	Fats, Oils, Shortenings
Butter	1/2 cup	112	113	114	115	116	117	118	Fats, Oils, Shortenings
Butter	1/4A lb.	112	113	114	115	116	117	118	Fats, Oils, Shortenings
Beans	1 cup	125	25	1	t	t	0.8	6	Vegetables A-E
Lima	1 cup	160	140	8	t	t	3	24	Vegetables A-E
Lima, dry,	1 cup	192	260	16	t	t	2	48	Vegetables A-E
Navy, bake	3/4 cup	200	250	11	6	6	2	37	Vegetables A-E
Turnip gre:	1 cup	145	45	4	1	0	1.8	8	Vegetables R-Z
Turnips, st:	1 cup	155	40	1	t	0	1.8	9	Vegetables R-Z
Watercress	1 cup	50	9	1	t	0	0.3	1	Fruits A-F
Apple juice	1 cup	250	125	t	0	0	0	34	Fruits A-F
Apple vine	1/3 cup	100	14	t	0	0	0	3	Fruits A-F
Tangerine:	1 med.	114	40	1	t	0	1	10	Fruits R-Z
Watermelon	1 wedge	925	120	2	1	0	3.6	29	Fruits R-Z
Biscuits	1	38	130	3	4	3	t	18	Breads, cereals, fastfood, grains
Bran flake:	1 cup	25	117	3	t	0	0.1	32	Breads, cereals, fastfood, grains
Bread, cr:	1 slice	23	60	2	1	1	0.1	12	Breads, cereals, fastfood, grains

PROPOSED SOLUTION

The objective of this proposal is to create a specialized dietary assessment tool tailored to Indian cuisine, enabling users to accurately assess their dietary choices by analysing images of Indian food. This solution will leverage machine learning techniques customized for the complex and diverse range of Indian dishes. YOLO (You Only Look Once) algorithm is the preferred choice for the dietary assessment tool due to its unmatched speed, single-shot detection, superior accuracy in object localization, high customizability, accessibility through open-source

implementations, and a proven track record in real-world applications. Additionally, it will incorporate a user-friendly interface to ensure accessibility and ease of use, ultimately contributing to improved dietary awareness and health outcomes.

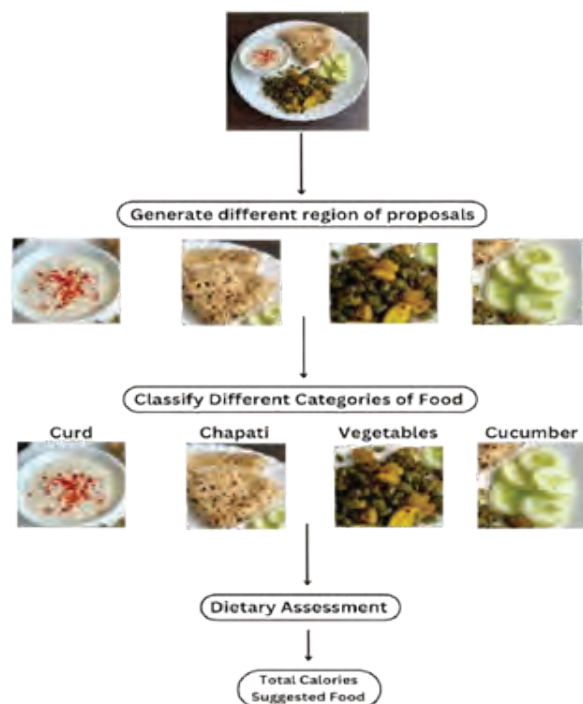


Fig. 2: Steps for food recognition and nutrient estimation

CONCLUSION

The reviewed research papers highlight the potential of machine learning-based dietary assessment as a transformative tool in the field of nutrition. The efficiency and scalability of machine learning models further add to their significance. With the capacity to process large volumes of dietary data quickly, these models enable the analysis of dietary patterns across diverse populations, making it feasible to identify trends and disparities related to diet and nutrition. This technology holds the promise of promoting healthier dietary habits, reducing the burden of diet-related diseases, and enhancing overall well-being. As we move forward, it is imperative to continue refining these models, ensuring their accuracy and applicability in diverse contexts, and bridging the gap between research and practical implementation. The adoption of machine learning-based dietary assessment has the potential to empower individuals and communities in their pursuit of improved health and nutrition.

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Development and Validation of Novel First Order Derivative UV-spectrophotometric Method for Telmisartan in Bulk and Formulation

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ABSTRACT

Telmisartan is one of the promising, long lasting antihypertensive agent act as an angiotensin II receptor blocker. Telmisartan used in single dosage form as well as in combined dosage form with other drugs like hydrochlorothiazide, amlodipine, cilnidipine, metformin, ramipril, azelnidipine. First order derivative spectroscopy using UV spectrophotometer is significant having ability to improve the sensitivity, enhance the spectral resolution, reduced the background noise. In present study developed and validate the first order derivative UV-spectrophotometric method for telmisartan in bulk and in tablet dosage form to improve the sensitivity of method. The method developed using methanol and water (60:40 v/v coefficient value near to 1. Method was validated as per the ICH) having $\lambda_{\max} 315 \pm 1$ nm. Linearity was found in the range 05 $\mu\text{g/ml}$ to 30 $\mu\text{g/ml}$ with regression guideline includes sensitivity, accuracy, precision, ruggedness, robustness, and all parameters were found within the acceptable range with percentage relative deviation (%RSD) less than 2. Hence the given analytical method was found to be novel, simple, specific, sensitive, précised and robust for the estimation of telmisartan in bulk and tablet dosage form.

KEYWORDS : Telmisartan, First order derivative, UV- Spectrophotometry, Validation.

INTRODUCTION

Telmisartan is orally active angiotensin II blocker chemically (IUPAC) known as 4-[(1, 4- dimethyl-2-propyl [2, 6 -bi-1H-benzimidazol]-1-yl) methyl]-[1,1-biphenyl]-2-carboxylic acid (Figure 1) act as antihypertensive by acting on AT-1 receptor in adrenal gland along with vascular smooth muscles^{1,2,3}. To achieve accuracy, precision and reproducibility and reliability of methods they need to be validate as per the International Conference on Harmonization (ICH) guidelines 4,5.

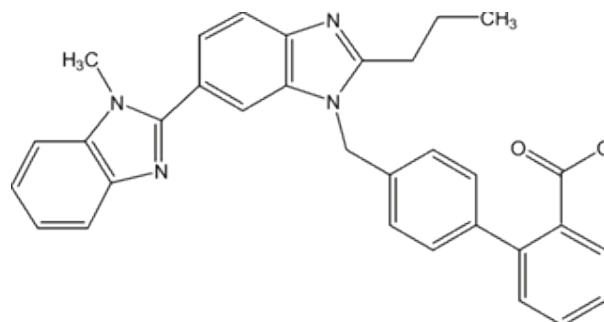


Fig. 1 Structural formula -Telmisartan

First Order Derivative Method

Derivative spectroscopy is one of the analytical technique which used to improve the sensitivity of method, reduced background interference, selectivity and resolution of particular spectra. Measurement techniques of derivative spectroscopy involves graphics measurement, numeric measurement, zero crossing techniques. The first derivative measure the change in absorbance with respect to wavelength. It can be expressed as

$D1(\lambda) = (dA(\lambda))/d\lambda$ where $D1(\lambda)$ is first derivative,

$dA(\lambda)$ is absorbance at selected wavelength λ .

The slope of the absorbance curve changes which indicating maxima and minima from original spectrum. The first derivative passes through the zero helps in finding absorption bond usually considered as $\lambda_{\max}$.^{6, 7}

MATERIAL AND METHOD

Material

Instrumentation: Shimadzu UV 1800 and Lab India

UV 3200 double beam spectrophotometers, Shimadzu electronic balance, Labman LMUC6 sonicator were used.

Reagents and Chemicals: Telmisartan standard drug samples were kindly received from J.B. Chemicals and Pharmaceuticals Limited, Mumbai. All chemicals and reagents were used of AR grade MERCK chemicals Ltd Mumbai such as methanol, distilled water prepared in the laboratory using Barnstead pattern distillation unit, marketed formulation containing telmisartan 20 mg purchased from local market.

Development of first order derivative UV-Spectrophotometric Method

Selection of wavelength maxima: For the selection of wavelength for further analysis, stock solutions having concentration 100 µg/ml telmisartan was prepared in solvent methanol: distilled water (60: 40). The stock solution further diluted separately to get 25 µg /ml. This solution was scanned in the ultraviolet spectroscopic (UV) range of wavelength i.e. 200-400 nm, the λ max of the drug was determined at the wavelength having maximum and acceptable absorption at zero order derivative and perform the first order derivative analysis and selected the wavelength λ 315 ± 1 nm.

Preparation of standard stock solutions: Weighed accurately and dissolved 10 mg of pure drug telmisartan in 100 ml graduated flask with small amount of solvent methanol: distilled water (60: 40), sonicate the it for 15 minutes at 30 to 35 °C and made up volume upto the mark using same solvent to get 100 µg /ml stock solution. The stock solution further used to made suitable dilutions like 05 -30 µg /ml for telmisartan.

Preparation of sample (marketed) solution: Weighed accurately 20 uncoated tablet containing telmisartan (20 mg) procured from the local market and calculated the average weight of per tablet. Crushed all the tablet and made the fine powered with the help of mortar and pestle, further accurately weighed the powdered mixture equivalent to 259.60 mg which was contain 20 mg of telmisartan. Dissolved the powder using solvent methanol: distilled water (60: 40) in 100 ml graduated flask, stirred with sonicator for 15 minutes at 30 to 35 °C and made up volume upto the mark using same solvent to get 100 µg / ml telmisartan. Filtered the solution with Whatmann filter paper and used to prepare required dilutions and used for further analysis.

Linearity and Range: From the 100 µg /ml standard stock

solution different aliquots having 5, 10, 15, 20, 25 and 30 µg /ml of telmisartan.

Determination of Limit of detection (LOD) and Limit of quantification (LOQ): It helps to find out lowest amount of analyte that able to detect and quantify from the sample.

Accuracy

Analyte recovery: Analyte recovery study was performed at 80 %, 100 %, 120 % spiked level. The recovery were determined with comparison to known amount added and spiked level of analyte expected to recovered in assay.

Precision: Intraday and interday precision were performed by selecting three different concentrations of analyte individually within the linearity range. For intraday six replicates for three different concentrations at three different time were determined. Interday precision performed on three different days.

Ruggedness

A method is considered as rugged when results are reproducible as measured with % relative standard deviation (% RSD) between different laboratories, different analysts and equipments. Here two different analysts and two different UV spectrophotometer were used.

RESULT AND DISCUSSION

Wavelength Selection: The prepare solutions of drug was scanned within 200- 400 nm and perform derivative spectra it was 315±1nm for telmisartan. Fig. 2

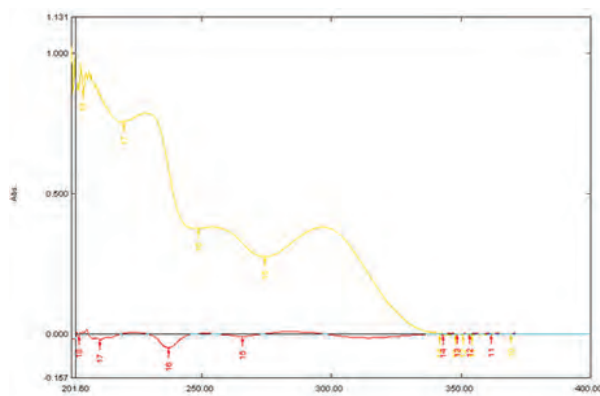


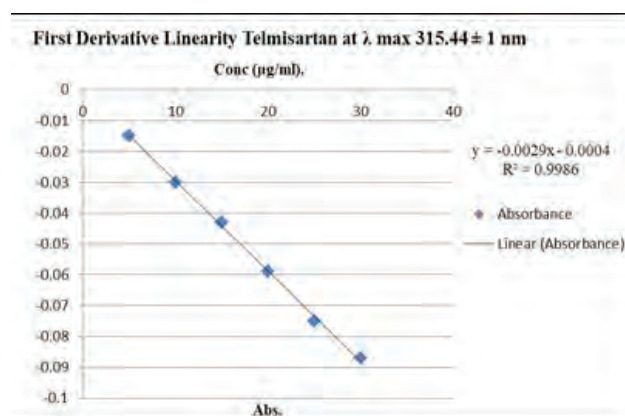
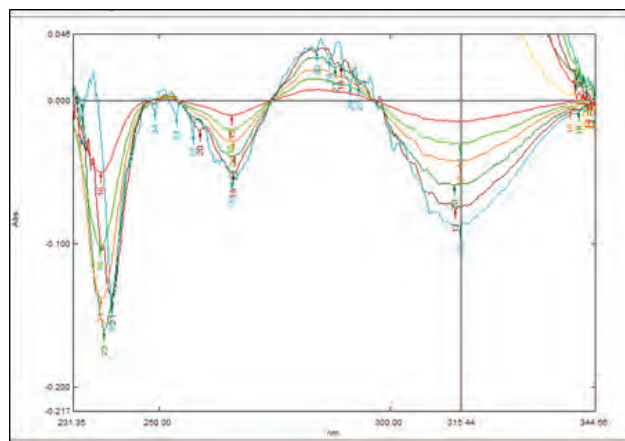
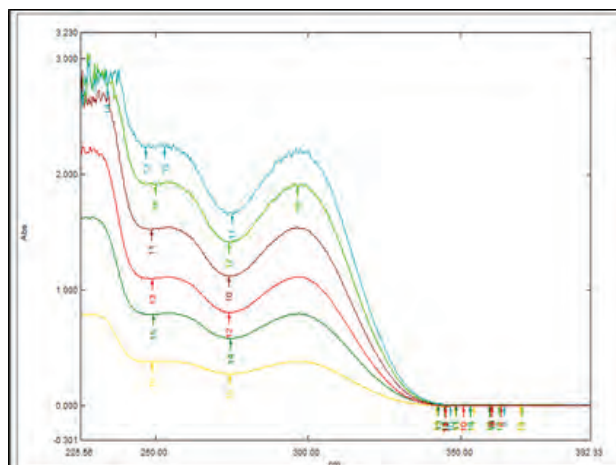
Fig. 2 Normal and derivative spectra of Telmisartan

Linearity and range: Linear regression value (r^2) of calibration curve shows good relationship between concentration and absorption. in given methods concentration range 05-30 µg /ml of telmisartan shows good linearity shown in Table 1, and Fig. 3, 4, 5.

Table 1 Calibration Curve Data for Telmisartan at 315±1nm

Concentration	Absorbance*	Standard Deviation	Relative Standard Deviation
5	-0.015	0.00020	1.3158
10	-0.03	0.00012	0.3612
15	-0.043	0.00058	1.3323
20	-0.059	0.00058	0.9841
25	-0.075	0.00115	1
30	-0.087	0.00058	1.5534

*mean of three reading

**Fig. 3 Linearity curve for Telmisartan****Fig. 4 First order derivative overlay spectra of different concentration of telmisartan****Fig. 5 Overlay spectra of different concentration of telmisartan**

Accuracy: The solutions for the recovery studies at 80 %, 100% and 120 % were prepared by addition method. Prepared solution were sonicated and filtered through Whatmann filter paper no.40 and analysed to get percentage recovery of analyte and percentage relative deviation (% RSD) of both the drugs and in both the methods were found to be less than 2 % shown in Table 2.

Table 2 Statistical Validation of Recovery Study

Level of recovery	Conc. Taken (µg/ml)	Amount added (µg/ml)	% Recovery	S. D	% R S D
80	20	16	98.27	0.2470	0.2513
100	20	20	98.69	0.0023	0.2337
120	20	24	99.10	0.0052	0.5289

*Average of six determinations, SD Standard Deviation

Determination Limit of Detection and Limit of Quantification:

By placing standard deviation (S.D.) values and slope (S) value into formulas from the linearity data, LOD 1.75 µg/ml and LOQ 5 µg/ml were calculated.

Determination of precision (Repeatability and intermediate precision): Precision is expressed in terms of percentage of relative standard deviation (% RSD) and for both the method it were observed less than 2 % shown in Table 3.

Table 3 Statistical Validation of Precision Study

Drug	Concentration Taken ($\mu\text{g/ml}$)	Interday precision*		
		Mean* ($\mu\text{g/ml}$)	S.D.	% RSD
Telmisartan	5	5.0667	0.0757	1.4944
	10	10.0833	0.0764	0.7575
	15	14.8433	0.1601	1.0786
Intraday Precision				
	5	5.0667	0.0757	1.4944
	10	10.1267	0.1419	1.4012
	15	14.8433	0.1601	1.0786

*Average of six determinations

Tablet formulation Analysis: Prepared an aliquots of the sample (marketed) solution having 20 $\mu\text{g/ml}$ telmisartan corresponds, recorded the absorbance of the solution and calculated the amount present in the sample. The percentage relative standard deviation for both the method were below 2% shown in Table 4.

Table 4 Statistical Validation of Tablet Formulation Analysis

Drug	Concentration Taken ($\mu\text{g/ml}$)	Mean* ($\mu\text{g/ml}$)	S.D.	% RSD
Telmisartan	20	19.85	0.0063	0.6339

*Average of six determinations

Ruggedness: The result of obtained from two different analyst by using two different made of instrument were found to be within the limits and overall RSD was below 2%.

CONCLUSION

The proposed method is simple, accurate précised and found accurate for bulk drug and marketed tablet formulation. This method can be useful for analysis of telmisartan in laboratories with accuracy and found cost effective.

CONFLICT OF INTEREST

The authors have no conflicts of interest regarding this investigation.

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Survey Paper: Fine-Grained Sentiment Analysis Using Attention Mechanisms in Machine Learning and Deep Learning

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ABSTRACT

Fine-grained sentiment analysis has gained significant attention in natural language processing (NLP) due to its ability to capture nuanced sentiment, such as emotional shades and aspect-level sentiments. Recent advancements in machine learning (ML) and deep learning (DL) have leveraged attention mechanisms to improve the performance of these tasks. Attention mechanisms enable models to focus on the most relevant parts of input text, enhancing their ability to perform tasks like aspect-based sentiment analysis and fine-grained classification. This survey paper discusses recent techniques, algorithms, and challenges in fine-grained sentiment analysis using attention mechanisms, highlighting studies from 2019 to 2024. The review also identifies gaps in current research and suggests potential directions for future studies.

KEYWORDS : *Telmisartan, First order derivative, UV- Spectrophotometry, Validation.*

INTRODUCTION

Sentiment analysis involves determining the emotional tone expressed in a piece of text. While traditional sentiment analysis focuses on classifying text as positive, negative, or neutral, fine-grained sentiment analysis seeks to classify sentiments with higher precision, accounting for subtle differences such as intensity, sarcasm, or mixed emotions. Fine-grained sentiment analysis becomes more complex when dealing with multiple aspects, where different segments of text convey distinct sentiments about different aspects of a subject. For example, in a product review, one part may praise the quality, while another may criticize the price. To address these challenges, attention mechanisms have become a crucial component in enhancing model performance, enabling the model to focus on the relevant aspects of input data. This paper reviews the state-of-the-art approaches in fine-grained sentiment analysis using attention

mechanisms in both machine learning and deep learning models. The focus is on recent studies that utilize attention mechanisms for aspect-based sentiment analysis, emotional shade identification, and nuanced sentiment classification.

FINE-GRAINED SENTIMENT ANALYSIS TECHNIQUES

2.1 Attention Mechanisms in Sentiment Analysis

Attention mechanisms allow models to prioritize certain words or phrases in a sentence based on their importance for the given task. This approach is particularly effective for sentiment analysis, as the sentiment of a sentence may not always be conveyed by the overall context but rather by specific words or phrases. Attention mechanisms help improve the focus of the model, leading to more accurate sentiment predictions

Algorithms Leveraging Attention Mechanisms

Table 1 Research paper Analysis of techniques to find out sentiment

Sr. No	Year	Title of study	Algorithm/Technique	Data set /Source	Gap Analysis
1	2024	Dual-Perspective Fusion Network for Aspect-Based Multimodal Sentiment Analysis	dual-perspective fusion network(DPFN)with local and global sentiment	Twitter datasets	Sentiment-related information from different modalities.

2	2023	Sentiment Analysis of News Headlines Based on Sentiment Lexicon and Deep Learning.	web news	online news data	lexicon sentiment analysis
3	2023	Analysis of Underlying Emotions in Textual Data Using Sentiment Analysis Which Classifies Text In to Positive, Negative or Neutral Sentiments	CNN and BI-LSTM	Go-Emotions (Demszky et al. (2020)) dataset	fine grained classification
4	2023	Aspect-level Sentiment Analysis Review: Recent Advances and Trends	survey paper		Multimodal sentiment analysis, performance of implicit aspect term extraction is not yet satisfactory.
5	2023	Design and Optimization of Loss Functions in Fine-grained Sentiment and Emotion Analysis	Sampling method	Kaggle	unbalanced Labels in Senti-mental/Emotional Analysis
6	2023	A Study of Collocations in Sentiment Analysis	Collocation method	Amazon review dataset from Kaggle	Collocation may be potential feature for SA
7	2023	Aspect Based Sentiment Aware Word Embedding for Cross Domain Sentiment Analysis	Neural Network	From web	to make efficient neural model for aspect based sentiment analysis
8	2022	Developing a Hybrid model with Shades of Sentiment for Understanding Teenagers' Academic Distraction Problems	Sentiment analysis using lexicon based approach	155 own data set	Performance of the model not satisfactory
9	2022	LSTM Based Sentiment Analysis on Conversations in Health	LSTM deep learning	Health data	multidimensional model, Aspect based sentiments
10	2022	Multi-grained Syntactic Dependency-aware Graph Convolution for Aspect-based Sentiment Analysis	MSD-GCN model. (multi-grained syntactic dependency-aware graph convolutional network model)	webnet	Performance of aspect-based sentiment analysis.
11	2022	Sentiment Analysis by Using Modified RNN and A Tree LSTM	LSTM Model with TREE	amazon food dataset	fine grained sentiment analysis still be enhanced
12	2021	Aspect-Based Attention LSTM for Aspect-Level Sentiment Analysis	ABABiLSTM	SemEval2014 data set and Twitter data set	improve the efficiency of model using aspect level sentiment analysis
13	2021	Exploring various emotion-shades for Marathi Sentiment Analysis	survey paper		need to be work on context based sentiment
14	2020	A review on sentiment analysis in psychometrical diagnosis	survey paper		Need work on multidimensional model of sentiment
15	2019	Fine-grained Sentiment Classification using BERT	pretrained BERT model	Stanford Sentiment Treebank	fine-grained sentiment classification task

Table 2 Imminent research done to identify human sentiments in medical field

Sr. NO	Title	Year	Algorithm/ Technique	Data set/source	language used for Data set	Gap Analysis
1	Long Short Term Memory-based Sentiment Analysis of Healthcare Reviews	2023	LSTM algorithm	Healthcare review data	English	Efficiency of LSTM model for large dataset
2	Deep Learning Based Sentiment Analysis on Drug Reviews.	2023	Deep learning and machine learning techniques LSTM and BiLSTM	medicine reviews from web	English	Accurate and reliable result of sentiment analysis
3	Exploring Drug Sentiment Analysis with Machine Learning Techniques.	2023	Machine learning algorithms	publicly available dataset of drug reviews	English	extracting valuable information from the vast amount of unstructured data
4	Hybrid CNN LBP using Facial Emotion Recognition based on Deep Learning Approach	2023	The Convolutional Neural Network (CNN) algorithm	not specify	English	Facial emotion Recognition System
5	LSTM Based Sentiment Analysis on Conversations in Health.	2022	LSTM deep learning	healthcare existing data	English	efficiency of the classification algorithm

Dual-Perspective Fusion Network (DPFN) (2024): This method combines local and global sentiment information, applied to Twitter datasets. It integrates dual-perspective fusion networks with attention mechanisms to improve sentiment-related information extraction from different modalities (text, image, etc.). This approach addresses the gap in the multimodal sentiment analysis field, where different data types often provide conflicting or complementary sentiment signals. Aspect-Based Attention LSTM (ABABiLSTM) (2021): The ABABiLSTM model uses attention mechanisms to focus on aspect-specific sentiment in text, distinguishing sentiment for individual aspects of a product or service. This model uses LSTM networks (Long Short-Term Memory) enhanced with attention mechanisms to handle aspect-level sentiment extraction in datasets like SemEval2014 and Twitter data. Despite the advancements, there remains room to improve the model's efficiency in real-time applications. LSTM with Tree Attention (2022): This model enhances the LSTM network with a tree-based attention mechanism, providing better handling of syntactic structures in text. Used with datasets like Amazon reviews, this model is designed for fine-grained sentiment analysis, focusing on improving accuracy in sentiment classification

tasks. Multi-grained Syntactic Dependency-Aware Graph Convolutional Networks (MSD-GCN) (2022): This model integrates syntactic dependency-aware graph convolution networks with attention mechanisms for aspect-based sentiment analysis. The attention mechanism allows the model to better understand how different parts of a sentence are related to specific aspects, leading to improved sentiment classification performance.

DATASETS USED IN FINE-GRAINED SENTIMENT ANALYSIS

Twitter Data: Widely used in sentiment analysis, particularly for multimodal analysis (e.g., DPFN model). Twitter datasets are valuable for fine-grained sentiment analysis due to the varied emotional expressions and informal language used. Amazon Reviews: A rich source for aspect-based sentiment analysis, Amazon reviews are frequently employed for training models that aim to classify sentiment for specific aspects (e.g., product quality, price, shipping). Go-Emotions Dataset (2020): This dataset, used in conjunction with CNN and Bi-LSTM models, contains fine-grained labels for different emotional tones, allowing for a detailed analysis of emotions beyond simple positive or negative sentiment.

Health Data: Several studies, such as LSTM-based sentiment analysis on healthcare conversations, use health-related data to assess sentiments around healthcare services or medical products. The nuances in healthcare sentiment make it an ideal field for fine-grained sentiment analysis with attention mechanisms.

CHALLENGES IN FINE-GRAINED SENTIMENT ANALYSIS

Despite advancements, there are still several challenges in fine-grained sentiment analysis, particularly when attention mechanisms are applied:

Implicit Aspect Term Extraction

While models like DPFN and ABABiLSTM have shown promising results in aspect-based sentiment analysis, the extraction of implicit aspect terms remains a challenge. Implicit aspects refer to those sentiments that are not directly mentioned but can be inferred from the context.

Handling Mixed Emotions

Mixed emotions, such as when a review expresses both positive and negative sentiments about the same entity, pose a significant challenge for fine-grained sentiment analysis. Existing models like BiLSTM and LSTM with Tree Attention struggle to identify and classify these mixed emotions accurately.

Domain Adaptation

Fine-grained sentiment analysis models often struggle with domain adaptation, especially when applied to specialized domains like healthcare or pharmaceuticals. A model trained on general datasets like Amazon reviews may not perform well on domain-specific datasets without fine-tuning.

Data Imbalance

Many sentiment datasets, especially those involving fine-grained emotional labels, suffer from class imbalance. This results in biased models that are more adept at predicting the majority class while struggling with the minority class. Techniques like sampling methods have been proposed to address this issue, but they remain a work in progress.

GAP ANALYSES IN SENTIMENT ANALYSIS RESEARCH

Aspect-Level Sentiment Analysis: Multiple studies, particularly in 2023, identified that implicit aspect term extraction techniques are still inadequate. This is a critical gap for improving the performance of aspect-level sentiment

analysis.

Context-based Sentiment Analysis: Several studies, including those in Marathi sentiment analysis, emphasized the need for better context understanding. Sentiments are often context-dependent, and current models struggle with regional languages or informal contexts.

Fine-grained Sentiment Analysis: This remains a key challenge across many studies. Fine-grained classification (such as distinguishing between various emotional shades or multi-dimensional sentiments) often results in lower accuracy, and current models like LSTM or BERT need further optimization to handle this task effectively.

Multimodal Sentiment Analysis: Although the fusion of modalities such as text, image, and audio is gaining traction (e.g., in DPFN), many approaches still struggle to fuse sentiment data from these diverse sources seamlessly.

Improved Attention Mechanisms

While attention mechanisms have improved model performance, further refinement is needed. Specifically, hierarchical attention networks, which allow models to focus on different levels of information (e.g., word-level, sentence-level), could enhance fine-grained sentiment analysis accuracy.

CONCLUSION

Fine-grained sentiment analysis using attention mechanisms has shown significant progress in improving the accuracy of sentiment classification tasks. Attention-based models, such as ABABiLSTM, DPFN, and MSD-GCN, have demonstrated their ability to enhance sentiment understanding at the aspect level and beyond. However, challenges such as implicit aspect extraction, mixed emotions, and domain adaptation remain significant obstacles. Future research should focus on refining attention mechanisms, improving cross-domain applicability, and addressing data imbalance to further advance the field of fine-grained sentiment analysis.

FUTURE SCOPE

We can explore the integration of more advanced transformer-based models, such as BERT, and further refinement of feature extraction techniques to capture even more intricate contextual information. Developing more robust models for cross-domain sentiment analysis remains a major challenge. Models must adapt to different types of text and handle domain-specific terminology while maintaining accuracy in fine-grained sentiment classification. Additionally, expanding the approach to handle multilingual data and different text domains can broaden its applicability and impact. With the rise of multimodal sentiment analysis (combining text, image, and audio data), future studies could

explore how attention mechanisms can be applied to fuse these modalities effectively. This approach could improve the analysis of sentiments in social media posts, product reviews, and other multimodal data sources.

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Emerging Role of ICT in Chemical Sciences

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ABSTRACT

Satellite systems, computers, networks, hardware, software, and electronic devices are all included in information and communications technology (ICT), along with the many services and applications that go along with them. The coupling of computer networks with telephone and audio-visual networks via a cabling or link system is also known as ICT. ICT makes knowledge sharing easier and more user-friendly while also removing space-related issues. The systematic examination of molecules, the design of new compounds, the structure determination of newly synthesized compounds, and other activities are all included in chemistry research.

This paper demonstrates that in order to alter the way that traditional teaching and learning are conducted, learners should possess ICT knowledge in addition to learning material. This can be achieved by updating chemical knowledge in the fields of academia and research by using online databases such as Scopus, Scifinder, Reaxys, etc. The need for ICT is growing daily, and it is crucial to develop intellectuals by offering top-notch instruction in order to advance international standards in the chemical sciences. Evaluation is one of the most crucial aspects of teaching and learning. As a result, ICT ought to be used to guarantee quality in the field of chemical sciences.

KEYWORDS : *ICT, Research, Group works activities, Virtual Laboratory, Chemical sciences.*

INTRODUCTION

Information and communications technology is referred to as ICT. ICT is a broad term that encompasses the technological resources and instruments used for information creation, management, storage, and communication. ICT is essential, valuable, and crucial to education in every nation. We can readily understand chemistry principles with the aid of ICT. Students should be encouraged to use the Chemistry Encyclopaedias that are currently available on mobile devices. ICT that can be used for broadcasting; this includes audio, print, and video. ICT makes communication easier and more accessible. With ICT, learners can communicate at any time and from any location, eliminating issues related to time and distance.

Communication tools like Synchronous and Asynchronous are useful for e-learning. Examples of synchronous communication tools are skype, google talk, yahoo messenger, video conferencing. The opposite of synchronous

is asynchronous, which includes tools like email, blogs, wikis, newsgroups, podcasts, YouTube, audio graphics, online forums, social networking sites. These tools provide good connection and create a free flow of knowledge and experiences as well as ease of testing new innovations.

By using ICT wisely, students can gradually improve their understanding of chemistry. ICT links different R&D and educational establishments. ICT is therefore one of the most important instruments for high-quality research. We have attempted to analyze the growing importance of ICT in chemical sciences in this research work.

SCOPE OF THE STUDY

We have attempted to analyse the role of ICT in chemical sciences in this work. ICT can be utilized to create online course materials, provide study materials, and share materials with students that are located far away in rural areas.

Objectives of the Study

- Role of ICT in the five main disciplines of Chemistry
- Tracing the role of ICT in Research
- Significant challenges for successful application of ICT in Chemical Sciences
- Suggestions for fully utilization of ICT

Why ICT?

- Today the learner's attitude is drastically changing thus use of ICT is important.
- ICT is the technology that makes communication efficient and easy to use.
- ICT solves problems related to space and saves the time. Therefore, it gives entry to sharing of knowledge.
- Through ICT the learners can gather and exchange information anywhere, anytime more effectively and can produce a global pool of knowledge.
- The students can prepare notes and power point presentations and can be used it for exams.
- The concept of 'e' includes e-mail, e-learning, e-shopping, e-health, e-banking, e-commerce, e-books, e-marketing, e-governance, e-exam, e-interview, etc. which provides fast response to users which ultimately increases interactivity.

Role of ICT in the disciplines of Chemistry

The five main branches of chemistry are physical chemistry, inorganic chemistry, organic chemistry, biochemistry and analytical chemistry. Various computing tools like word processors, presentation software, database maintenance and spreadsheets, can be used in chemistry. The knowledge base sources like online encyclopaedia, libraries, journals, magazines added valuable role in the disciplines of Chemistry.

Tracing the role of ICT in Research

"Research" is defined as imaginative, critical, and meticulous investigation that seeks to further our understanding. In chemical science, research entails the methodical and scientific examination of an issue. With the right research methods and statistical analysis, it is possible to solve the crucial problem related to chemistry. ICT therefore plays a significant part in it. Most of the journals are having data on their website so learner can go through web page of concerned journal and acquire essential knowledge.

Online databases like Scifinder, Reaxys and Scopus are useful for literature survey, for preparing manuscripts, research proposals and scientific paper writing. Any topic related to

organic chemistry can be searched on Scifinder, Reaxys or on Scopus to get an idea regarding novelty of that topic. Scifinder and Reaxys is an excellent database and web-based tool for the retrieval of chemistry information and data from published work. It indexes "journals, patents, dissertations, conference proceedings, books, technical reports and many more." The information includes several chemical reactions, substance data, its chemical properties, synthetic plan as well as experimental procedures from selected journals and patents. It also frequently indicates the source of funding for a certain study. Scifinder can be used to discover who is researching a topic that interests you; it can also encourage cooperation and collaboration among academics. It also frequently indicates the source of funding for a certain study. Scifinder can be used to discover who is researching a topic that interests you; it can also encourage cooperation and collaboration among academics.

So, researchers can go through this type of databases to collect information about any topic of chemistry research. They can find out laboratory procedures for synthesis and can plan the laboratory work accordingly. As both the databases are providing chemical and physical properties of substances, researchers can go through this and can be benefited by following safety practices in chemical laboratory. The information obtained from these databases will be helpful for researcher to verify analysis reports like physical constant, IR, NMR, X-ray data for most of the chemical compounds with authentic database.

Following free services can be used to manage & share research in Chemistry

1. Mendeley (www.mendeley.com) : It is a free reference manager and designed for researchers, students and academics.
2. Dropbox (www.dropbox.com) : It is a modern workspace used to share files, collaborate on projects, and to bring best ideas to life.
3. Google Drive is developed by Google and used to file storage and synchronization. Google Docs, Google sheets, and Google Slides are used for collaborative editing of documents, spreadsheets, presentations, drawings, forms etc. from any device or location.

Virtual Laboratory with telecommunication facilities

A virtual laboratory on a personal computer can be used to teach the chemistry lab experimental processes. The virtual laboratory strategies that allow students to make the choices they would in a real laboratory setting can incorporate instructional laboratory duplication. After attending the same in the chemistry lab, the student might seek further online

help. This kind of blended learning strategy would enhance the concepts and abilities he learned through practical exercises in the classroom and lab. Therefore, the potential of these virtual laboratory materials should be known to the chemistry professors.

Existing Virtual Labs

The topics of chemistry practical which are already present on the net for virtual lab are: Organic Qualitative Analysis, Inorganic Qualitative Analysis, Organic Synthesis, Fundamental Experiments in Quantum Chemistry, Properties of gases, Titration Experiments and Instrumental Experiments.

ICT tools useful for Chemistry

1. LinkedIn (www.linkedin.com) : It is social network designed for career and business professionals to connect, which is a great platform to search for job openings and to connect with HRs of preferred companies.
2. Academia.edu (www.academia.edu) : It is a commercial social networking website for academics and students which is used to share research papers, monitor their impact, and the research in a particular field.
3. ResearchGate (www.researchgate.in) : It is social networking website for scientists and researcher which is used to share research papers, and answer questions, and find collaborators.
4. Google Scholar (<http://scholar.google.com>) : It is a freely accessible web search engine which helps to discover scholarly sources that exist on your topic.
5. You tube (www.youtube.com) : Learners can go through this to find out solutions for various chemistry related problems. For e.g. Mechanistic pathway for organic reactions, how metal complex is formed. It is also used to find out SOP for various simple chemistry instruments like PH meter, potentiometer, colorimeter etc. and sophisticated instruments like UV-Visible spectrophotometer, IR, NMR, Mass Spectrometer, GC, LCMS, HPLC, etc.
6. Wikis (www.wiki.com) : If learner have doubt on any topic of chemistry they can go through this to get knowledge regarding that topic.
7. Google Earth (www.google.com/earth/explore/products/desktop.html) : It will be useful for Chemical industrialist or researchers to find out the exact locations for planning in industry set-up.
8. Presentation Tools like Slide share (www.slideshare.net) : This will be helpful for researchers to exchange their

knowledge and views of chemistry in the form PPT or PDF.

9. Blogs (www.blogger.com) : It can be useful for communication and publication of information on the World Wide Web.
10. Google maps (<https://maps.google.com>) : It can be used to trace out the locations of various chemical industries, academic institute and research institutes.

Significant challenges for successful application of ICT in Chemical Sciences

1. The lack of infrastructure, especially at colleges, for employing ICT gadgets.
2. Employees are reluctant to use and learn how to use ICT resources.
3. Academics are not using technologies for teaching and learning or organizing research.
4. Limited ICT infrastructure remains a major barrier.
5. Still, there is threatening problem of confidentiality while using ICT.
6. To create an environment for actual implementation of the strategy.
7. As long as ICT is used properly, supports legitimate research, and doesn't take away from or divert from the planned study project, it can be a highly useful tool in research.

Suggestions for fully utilization of ICT

1. We can see that research is a demanding task that can be completed with the least amount of work while maintaining precision; ICT is a vital tool for this.
2. By establishing a National Knowledge Network, ICT may introduce the concept of collaborative research.
3. Digital libraries can vary in size and can be maintained by individuals or organizations.
4. Corrections of mistakes of chemistry laboratory should be made in the possible shortest period.
5. By creating a database, all qualified faculty members at universities and colleges should be utilized for evaluation tasks.
6. Word-play, crossword, and puzzle exchange via WhatsApp: Using WhatsApp, the instructor can send students words, sentences, or images, and then ask them to explain, narrate, or compose a brief piece on chemistry.

7. Through blogs, chat rooms, Twitter, Facebook, and other similar platforms, students can create their own community to exchange their subject-matter expertise.
8. Change the way you publish, move to open access and check publisher copyright agreement properly.
9. Placing an article or version thereof on your own website is one of the important steps.
10. Today's learners are different, therefore create or maintain your online presence.

CONCLUSION

In chemical science, ICT is a helpful instrument for efficiency, dependability, and transparency. ICT should be used to its best potential in order to modify the current system. ICT is therefore the most effective tool available to chemical science researchers.

With the careful use of ICT, a student's knowledge can be gradually expanded, and they should always be very

interested in, enthusiastic about, and knowledgeable about chemistry subjects.

ICT promotes the growth of an autonomous research culture in the field of chemical sciences since it saves time, generates interest, makes learning effective, reduces learning costs, and solves the space issue.

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A Review on Early Detection and Progression Prediction of Diabetic Retinopathy Using Multimodal Analysis

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ABSTRACT

Diabetic Retinopathy (DR), a major complication of diabetes mellitus, is a leading cause of vision impairment and blindness in the working-age population globally. The intricate nature of DR, characterized by gradual retinal damage due to prolonged high blood sugar levels, makes its early detection and management critical. However, the current landscape of DR diagnosis and management faces significant challenges, primarily stemming from the limitations in existing diagnostic methods and the lack of comprehensive patient data integration. This work addresses these challenges by proposing a novel approach that leverages multimodal data fusion, utilizing machine learning (ML), deep learning (DL), and artificial intelligence (AI) techniques, aiming to enhance the accuracy, pre-emption, and clinical management of DR.

KEYWORDS : *Diabetic retinopathy, Deep learning, Fundus images, OCT scans.*

INTRODUCTION

The prevalence of diabetes and its complications, including DR, is on a rising trajectory, making it a significant public health concern. The early stages of DR often exhibit no symptoms, and when left undetected or untreated, it can progress to more severe stages, leading to vision loss. The traditional methods for DR screening and diagnosis, predominantly relying on fundus photography, have limitations in terms of sensitivity, especially in the early stages of the disease. Moreover, these methods do not consider other potential risk factors captured in various patient data modalities, such as blood reports and historical health records, which can provide valuable insights into the patient's overall health status and the progression of DR.

Recognizing these gaps, this work introduces a comprehensive framework that integrates multiple data modalities to enhance the detection and management of DR. The proposed model synergizes data from fundus images, advanced eye scans (like OCT and Angiography), blood analysis reports, patient demographics, and historical health records. This integration is achieved through advanced ML and DL techniques, which not only improve the classification accuracy of DR stages but also enable the pre-emption of disease progression through predictive analytics.

The Introduction of this multimodal approach is a significant leap forward in DR management. By encompassing a broader spectrum of patient data, the model facilitates a more nuanced understanding of DR, transcending the constraints of single-modality analyses. This holistic view allows for the early detection of DR, even in asymptomatic stages, and aids in predicting the disease trajectory, thus opening avenues for timely and personalized intervention strategies.

Moreover, this work extends beyond clinical diagnostics to encompass AI-driven clinical and non-clinical recommendations. By analyzing the integrated data, the model generates personalized treatment plans and lifestyle modification suggestions tailored to the individual patient's condition and risk profile. This approach not only enhances the efficacy of DR management but also fosters patient engagement and adherence to treatment regimens.

The introduction section of this work sets the stage for a detailed exploration of the proposed multimodal fusion model, its implementation, and its potential to revolutionize DR detection and management. Through this work, we aim to contribute significantly to the field of diabetic care, offering new perspectives and tools for healthcare professionals in combating one of the most challenging complications of diabetes.

REVIEW OF LITERATURE

The field of Diabetic Retinopathy (DR) analysis has seen significant advancements through the integration of various

computational approaches and imaging techniques. This literature review synthesizes key contributions from recent research, emphasizing the development and application of various models in DR detection and classification.

Table 1 Review of Literature

Reference	Method Used	Findings	Limitations
[1] Automatic Diagnosis of Different Grades of Diabetic Retinopathy and Diabetic Macular Edema Using 2-D-FBSE-FAWT	2-D-FBSE-FAWT, IoT, Deep Learning	Automated diagnosis for various DR grades using advanced imaging. Integration of IoT for efficient healthcare.	Limited explanation of IoT integration impact.
[2] Internet of Things and Deep Learning Enabled Diabetic Retinopathy Diagnosis Using Retinal Fundus Images	IoT, Deep Learning	DR diagnosis with retinal fundus images using IoT. Potential of IoT in medical imaging.	Limited discussion on IoT implementation challenges.
[3] Deep Learning Techniques for Diabetic Retinopathy Classification: A Survey	Deep Learning	Survey of deep learning techniques in DR classification.	Does not provide specific findings but summarizes techniques.
[4] Explainable Diabetic Retinopathy Detection and Retinal Image Generation	Deep Learning	Emphasis on explainable DR detection in AI models.	No direct findings but highlights the importance of inter-pretability.
[5] RTNet: Relation Transformer Network for Diabetic Retinopathy Multi-Lesion Segmentation	RTNet, Deep Learning	Introduction of RTNet for multi-lesion segmentation in DR.	Limited discussion on real-world applicability.
[6] Optimizing Deep Learning Model Parameters Using Socially Implemented IoMT Systems for Diabetic Retinopathy Classification Problem	Socially Implemented IoMT, Deep Learning	Optimization of model parameters using IoMT systems.	Lack of detailed performance improvements.
[7] Robust Collaborative Learning of Patch-Level and Image-Level Annotations for Diabetic Retinopathy Grading From Fundus Image	Collaborative Learning, Deep Learning	Robust collaborative learning for enhanced DR severity classification.	Limited discussion on scalability.
[8] Multi-Stream Deep Neural Network for Diabetic Retinopathy Severity Classification Under a Boosting Framework	Multi-stream Deep Neural Networks, Deep Learning	Enhanced DR severity classification using multi-stream networks.	Doesn't address specific limitations.
[9] Vision Transformer Model for Predicting the Severity of Diabetic Retinopathy in Fundus Photography-Based Retina Images	Vision Transformer, Deep Learning	Implementation of Vision Transformer for predicting DR severity.	Limited discussion on comparative performance.
[10] DR-GAN: Conditional Generative Adversarial Network for Fine-Grained Lesion Synthesis on Diabetic Retinopathy Images	DR-GAN, Generative Adversarial Networks	Introduction of DR-GAN for fine-grained lesion synthesis.	Limited discussion on practical applications.
[11] Segmentation Using the IC2T Model and Classification of Diabetic Retinopathy Using the Rock Hyrax Swarm-Based Coordination Attention Mechanism	IC2T Models, Image Segmentation	Exploration of image segmentation using IC2T models for DR.	Lack of discussion on model complexities.
[12] A Faster RCNN-Based Diabetic Retinopathy Detection Method Using Fused Features From Retina Images	Faster RCNN, Image Segmentation	DR detection with Faster RCNN-based image segmentation.	Limited discussion on real-world applications.

[13] Grading of Diabetic Retinopathy Images Based on Graph Neural Network	Graph Neural Networks, Grading DR Images	Leveraging graph neural networks for grading DR images.	Limited discussion on computational complexity.
[14] Graph Adversarial Transfer Learning for Diabetic Retinopathy Classification	Graph Neural Networks, Adversarial Transfer	Utilizing graph neural networks for adversarial transfer learning in DR.	Limited discussion on transferability.
[15] Uncertainty-Aware Deep Learning Methods for Robust Diabetic Retinopathy Classification	Uncertainty-Aware Deep Learning, AI Models	Focus on uncertainty-aware methods for robust DR classification.	Limited exploration of real-world uncertainty management.
[16] EDR-Net: Lightweight Deep Neural Network Architecture for Detecting Referable Diabetic Retinopathy	EDR-Net, Lightweight AI Architecture	Introduction of EDR-Net, a lightweight AI architecture for healthcare.	Limited discussion on comparative efficiency.
[17] Ensembled Deep Convolutional Generative Adversarial Network for Grading Imbalanced Diabetic Retinopathy Recognition	Ensembled Deep CNN Models, Hybrid Models	Exploration of ensembled deep CNN and hybrid models for DR recognition.	Limited discussion on the ensemble's impact.
[18] Systematic Development of AI-Enabled Diagnostic Systems for Glaucoma and Diabetic Retinopathy	AI-Enabled Diagnostic Systems	Systematic development of AI-enabled diagnostic systems in healthcare.	Doesn't provide specific findings but highlights the integration of AI.
[19] Diabetic Retinopathy Detection and Grading: A Transfer Learning Approach Using Simultaneous Parameter Optimization and Feature-Weighted ECOC Ensemble	Transfer Learning, Deep Learning	Utilization of transfer learning in DR analysis.	Limited discussion on model fine-tuning.
[20] A Hybrid Convolutional Neural Network Model for Automatic Diabetic Retinopathy Classification From Fundus Images	Hybrid CNN Models, Deep Learning	Use of hybrid CNN models for enhanced DR detection.	Limited discussion on the hybrid model's performance.
[21] Automatic Severity Classification of Diabetic Retinopathy Based on DenseNet and Convolutional Block Attention Module	DenseNet, Attention Mechanisms	Introduction of DenseNet with attention modules for DR analysis.	Limited discussion on practical implementation.
[22] Artificial Intelligence-Based Teleophthalmology Application for Diagnosis of Diabetic Retinopathy	AI-Based Teleophthalmology Applications	Advancements in AI-based teleophthalmology applications.	Limited discussion on teleophthalmology scalability.
[23] Joint Learning of Multi-Level Tasks for Diabetic Retinopathy Grading on Low-Resolution Fundus Images	Joint Learning, Low-Resolution Images	Joint learning for DR grading on low-resolution fundus images.	Limited exploration of low-resolution image challenges.

In summary, the recent literature in DR analysis demonstrates a trend towards more sophisticated, integrated, and patient-centric approaches. The utilization of advanced AI techniques, including deep learning, transfer learning, and ensemble methods, combined with innovative imaging and segmentation techniques, has significantly enhanced the accuracy and efficiency of DR detection and classification. These advancements not only improve diagnostic capabilities but also contribute to more personalized and accessible diabetic care.

RESEARCH GAPS

Identifying research gaps in the context of Diabetic Retinopathy (DR) analysis using multimodal data is crucial

for advancing the field. The following are key research gaps identified from the existing literature:

1. **Limited Integration of Multimodal Data:** While there are studies utilizing multimodal data for DR analysis, most focus on combining only two types of data, such as fundus images and OCT. Comprehensive integration that includes a broader range of modalities, such as blood biomarkers, patient demographics, and historical health records, alongside imaging data, is still relatively unexplored. This gap indicates a need for models that can effectively fuse and interpret a wider array of data types for a more holistic understanding of DR.
2. **Early Detection and Progression Prediction:** Current

models are effective in diagnosing existing DR but are less adept at early detection, particularly in asymptomatic stages. Moreover, there's a lack of emphasis on predicting the progression of DR. Research is needed to develop predictive models that not only diagnose DR but also forecast its progression, enabling preemptive interventions.

3. **Personalization of Treatment Recommendations:** Most existing models focus on diagnosis and classification of DR, with less attention given to personalized treatment recommendations. There is a research gap in models that can analyse multimodal data to generate personalized clinical and non-clinical recommendations, catering to the specific needs and risk profiles of individual patients.
4. **Interpretability and Clinical Usability of AI Models:** Although AI and deep learning have shown promise in DR analysis, the interpretability of these models remains a challenge. The black-box nature of deep learning makes it difficult for clinicians to understand and trust the decision-making process. Research is needed to develop AI models that are not only accurate but also transparent and interpretable in clinical settings.
5. **Scalability and Accessibility:** Many advanced DR analysis models require substantial computational resources, which may not be accessible in resource-limited settings. There is a need for scalable and efficient models that can be deployed in diverse clinical environments, including those with limited resources.
6. **Integration of Lifestyle and Environmental Factors:** The impact of lifestyle and environmental factors on DR progression is an underexplored area in multimodal data analysis. Research incorporating these factors could provide more comprehensive insights into DR management and prevention strategies.
7. **Longitudinal Data Analysis:** Most studies are cross-sectional, focusing on data at a single point in time. There's a lack of longitudinal studies that analyze patient data over time to understand the dynamics of DR progression and response to treatments.

By addressing these research gaps, the work WILL significantly advance the field of DR analysis, offering more accurate, comprehensive, and personalized approaches to managing this complex condition.

The primary aim of this work is to develop and validate an advanced, multimodal data-driven model for the analysis, prediction, and management of Diabetic Retinopathy (DR). The specific aims are:

To Develop an Advanced Multimodal Fusion Model:

Create a comprehensive framework that integrates various data types, including fundus images, OCT scans, blood reports, patient demographics, and historical health records, using sophisticated ML, DL, and AI techniques.

To Enhance Early Detection and Progression Forecasting of DR:

Develop algorithms capable of identifying early-stage DR and predicting its progression, focusing on improving early intervention and management strategies.

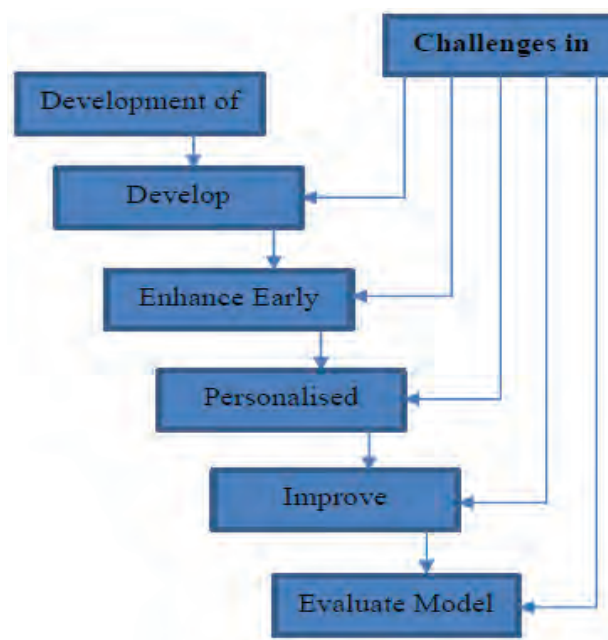


Fig. 1 Challenges in DR Analysis

To Personalize DR Management Strategies:

Utilize the integrated data model to generate tailored clinical and non-clinical recommendations, aiming to offer personalized treatment and lifestyle modification plans for patients.

To Improve Clinical Usability and Interpretability of AI Models:

Design AI algorithms that are transparent and interpretable, ensuring that healthcare professionals can effectively understand and utilize the model's insights.

FUTURE WORK

Development of an Advanced Multimodal Fusion Model. This work will create a comprehensive model integrating various data modalities, including fundus images, OCT scans, blood

reports, patient demographics, and historical health records. This model, leveraging advanced machine learning, deep learning, and AI techniques, marks a significant advancement over traditional single-modality approaches in DR analysis.

Enhanced Early Detection and Progression Prediction. The research demonstrated the model's capability in early detection of DR, particularly in asymptomatic stages, and in predicting disease progression. This achievement is crucial for early intervention, potentially preventing the progression to more severe stages of DR.

Personalization of DR Management Strategies. A notable contribution of this work is the generation of personalized clinical and non-clinical recommendations based on the integrated data analysis. This approach represents a shift towards more individualized patient care in DR management, aligning with the broader goals of personalized medicine.

Improved Clinical Usability and Interpretability of AI Models. The research focused on developing AI models that are not only accurate but also interpretable and user-friendly for clinicians. This effort enhances the trust and usability of AI in clinical settings, bridging the gap between advanced computational methods and practical clinical applications.

Assessment of Model Scalability and Accessibility

CONCLUSION

The primary aim of this work is to develop and validate an advanced, multimodal data-driven model for the analysis, prediction, and management of Diabetic Retinopathy (DR). The specific aims are:

To Develop an Advanced Multimodal Fusion Model: Create a comprehensive framework that integrates various data types, including fundus images, OCT scans, blood reports, patient demographics, and historical health records, using sophisticated ML, DL, and AI techniques.

To Enhance Early Detection and Progression Forecasting of DR: Develop algorithms capable of identifying early-stage DR and predicting its progression, focusing on improving early intervention and management strategies.

To Personalize DR Management Strategies: Utilize the integrated data model to generate tailored clinical and non-clinical recommendations, aiming to offer personalized treatment and lifestyle modification plans for patients.

To Improve Clinical Usability and Interpretability of AI Models: Design AI algorithms that are transparent and interpretable, ensuring that healthcare professionals can effectively understand and utilize the model's insights.

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Admission Assistance Voice BOT

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ABSTRACT

Voice based chatbots are AI-driven systems which are designed to understand and respond to user queries using natural language processing and voice recognition. These systems are increasingly adopted for different applications to enhance user experience through interactive and efficient communication.

In the context of admission counselling, voice-based chatbot can assist prospective students by answering admission and college related queries and guiding through admission process and details efficiently. It can handle large number queries and reduce the workload of human staff.

Our system is a voice-automated chatbot specifically for the admission process. It integrates AI capabilities to provide responses to the queries of the students and their parents. It can handle FAQs and handle and guide students in real-time. By streamlining repetitive tasks, it allows admission counsellors to focus on more complex admission process. Evaluation showed that the system reduced response time by 50% and showed its scalability by handling up to 1000 queries per day with consistent accuracy.

This chatbot can be deployed in educational institutions and student help desks to improve accessibility of their services. Additionally, it can be extended to career counselling centres too.

KEYWORDS : AI, NLP, ASR, FAQs, SBERT.

INTRODUCTION

In a study by Fletcher, (2018), the role of intelligent systems in the educational sector cannot be over emphasized, with intelligence having addressed various issues.[1] Voice-based chatbots are interactive systems that leverage artificial intelligence (AI) to process and respond to user queries through voice commands. These chatbots use technologies like Natural Language Processing (NLP) and Automatic Speech Recognition (ASR) to understand spoken language, interpret the intent, and provide accurate responses. The system typically consists of key components such as a user interface, a speech-to-text module, a natural language understanding engine, and a response generation module. The process starts

with capturing the user's voice input, converting it into text, analyzing the intent, and then generating a contextually relevant voice-based output. A general block diagram of such a system illustrates the interaction between these modules, showcasing the seamless flow from user query to final response.

It integrates speech-to-text conversion for voice input, PDF text extraction and parsing for creating a knowledge base, and semantic search to retrieve the most relevant answers. Finally, the system uses text-to-speech conversion to provide spoken responses, enabling seamless interaction between the user and the system. Fig. 1 describes all the processes and their interaction mentioned above.

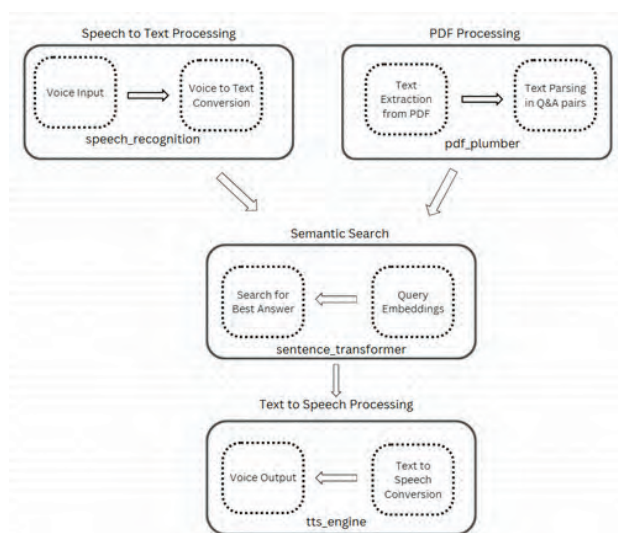


Fig. 1 A general block diagram of Voice Bot

The admission process in educational institutions involves handling numerous queries related to courses, eligibility, fees, application deadlines, and other concerns. Manually managing this volume of queries can be overwhelming, leading to delays, inconsistencies in responses, and increased workload for admission staff. This can result in prospective students experiencing frustration and dissatisfaction. Additionally, traditional methods of communication, such as phone calls and emails, often lack the immediacy and efficiency needed to handle large-scale inquiries, especially during peak admission seasons.

In this scenario, a voice-based chatbot can act as a game-changer by automating repetitive tasks and providing instant responses to common queries. Such a system can operate 24/7, ensuring accessibility even beyond working hours, and can handle multiple queries simultaneously without any decline in performance. By integrating with institutional databases, the chatbot can provide precise information, reducing errors and ensuring consistency. It can also guide students through the admission process, assist with form filling, and send reminders about deadlines. It leverages advanced AI technologies like NLP, ASR, and Machine Learning (ML) to understand and respond to queries in a conversational manner. The chatbot is built using Python for backend processing, TensorFlow for machine learning models, and Google Cloud Speech-to-Text API for voice recognition. For seamless interaction, the frontend is developed using React.js, ensuring a user-friendly interface, while the backend integrates with a MongoDB database to store and retrieve institutional data. The system is also equipped with APIs for real-time data updates and functionalities.

The remainder of this paper is organized as

follows: Section 2 provides an overview of related work and existing solutions. Section 3 details the architecture and implementation of our voice-based chatbot system. Section 4 presents the technologies used in our voice-based chatbot system. Section 5 presents the evaluation methodology and results, highlighting the performance metrics of the chatbot. Finally, Section 6 concludes the paper with insights and the scope for further research.

LITERATURE SURVEY

The development of an “Admission Assistant Robot” harnesses the capabilities of Artificial Intelligence (AI) and Natural Language Processing (NLP) to streamline administrative processes in education. Recent advancements in voice and conversational AI highlight the transformative potential of such technologies

Voice assistants, a key component of conversational AI, have demonstrated significant potential in managing tasks such as information dissemination, query resolution, and navigation through complex systems. As explored by Parihar et al., these assistants utilize Automatic Speech Recognition (ASR) and dialogue management systems to interact with users in a natural and intuitive manner [6].

AI chatbots, another critical element of conversational AI, have proven to be effective tools for enhancing education and administrative efficiency. According to Labadze et al., these chatbots are particularly valuable for personalized learning, providing timely assistance, and reducing educators’ workloads. In the context of an Admission Assistant Robot, similar capabilities can be used to automate FAQs, guide students through forms, and provide status updates, all while ensuring a seamless user experience [3].

Further research on voice assistants by Huang (2024) discusses their integration into diverse environments, noting their ability to improve accessibility and engagement in both personal and professional contexts. For example, the use of voice assistants for personalized student interactions in China and task management in global offices underscores their versatility [5].

Maria Gabriela Campuzano investigated the role of Wolfram Alpha in learning analytic geometry. Her work, “Learning Analytic Geometry with the aid of Wolfram Alpha,” focuses on the positive impact of Wolfram Alpha on student achievement and their attitudes toward the tool. Campuzano selected Wolfram Alpha for its user-friendly interface, comprehensive results, step-by-step solutions, and visually appealing presentations. The study used a quasi-experimental design, with students separated into experimental and control groups. The data analysis involved comparing pre-test

and post-test scores using t-tests. Student perspectives on Wolfram Alpha were collected through questionnaires and analysed using descriptive statistics. Notably, the research took place during the disruption of face-to-face classes due to the COVID-19 pandemic and involved an online pre-calculus course. The results demonstrate that Wolfram Alpha enhances students' academic performance by creating interactive and engaging learning environments that effectively utilise ICT. Students showed enthusiasm for Wolfram Alpha, advocating for its inclusion in all pre-calculus courses. Based on these findings, Campuzano encourages teachers to consider incorporating Wolfram Alpha into their mathematics instruction.[7]

Veronika Rihova, Eva Jilkova, and Jan Wossala explored the application of Wolfram Alpha in the realm of mathematics and economics education. Their paper, "WOLFRAM ALPHA IN MATHEMATICS AND ECONOMICS," examines the usefulness of Wolfram Alpha as a teaching tool, specifically in financial mathematics. The researchers employed a questionnaire survey to collect data, and their findings support the idea that Wolfram Alpha is a valuable tool in contemporary educational approaches.[8]

The paper titled "Voice Assistants and Smart Speakers in Everyday Life and in Education" explores the integration of AI-powered voice assistants and smart speakers in daily routines and their potential for educational applications. It highlights how technologies like Natural Language Processing (NLP) and cloud computing enable these devices to interact naturally with users, making them increasingly prevalent in households. The study investigates usage patterns among different age groups, noting that adults prioritize convenience, children treat them as social companions, and elderly individuals benefit from their accessibility features.

For educational purposes, voice assistants demonstrate promise in personalized learning and engagement, especially for language learning and assisting children with special needs. However, their adoption in classrooms faces hurdles due to privacy and security concerns, alongside the need for proper teacher training. The paper emphasizes the potential of these devices to enhance learning experiences while addressing challenges like limited language support and privacy issues. This study calls for further research to optimize the role of voice assistants in education and bridge the gap between home and classroom learning environments. [11]

Voice assistants have begun to integrate into people's lives. It has a positive effect on the society as well as on the individual. For office, artificial intelligence voice assistant can help people work efficiently. For individuals, voice assistants can

not only provide convenience in life. To a certain extent, it can make up for the lack of people's emotions. Some people are willing to chat with a voice assistant after they start using it, which also has a lot to do with the faster pace of life. While voice assistants are not as emotionally rich as people, voice assistants can be a qualified listener. It can also be seen that people have emotional dependence on voice assistants. In addition to people's reliance on voice assistants, the development of voice assistant technology also involves emotional issues. For example, the fact that Apple's voice assistant Siri married Amazon's voice assistant Alexa, although a marketing ploy, has also raised questions about whether voice assistants have feelings. Although it is known that artificial intelligence voice assistants are generated by computer programming. But with the development and progress of science and technology, it will be a question worth thinking about whether artificial intelligence will appear human emotions autonomously.[12]

In conclusion, the literature underscores the transformative potential of AI and conversational technologies in education. The development of an Admission Assistant Robot can draw on advancements in voice recognition, chatbot integration, and administrative AI systems to enhance efficiency, reduce manual intervention, and improve user satisfaction.

METHODOLOGY

The objective of this research is to develop an intelligent and accessible system that processes spoken queries, retrieves semantically accurate answers from a pre-defined repository of question-answer pairs, and delivers these answers audibly to the user. By integrating advancements in Automatic Speech Recognition (ASR), Natural Language Processing (NLP), and semantic search, the proposed system aims to enhance human-computer interaction, particularly in scenarios where textual input/output is inconvenient or impractical. The methodology leverages tools and technologies such as pdfplumber for document processing, Sentence-BERT (SBERT) for generating semantic embeddings, and pyttsx3 for converting text to speech. The following subsections detail the system pipeline and its components.

Query Processing

The system begins with the user providing a spoken query. This input is captured and processed using Automatic Speech Recognition (ASR) technology, which converts speech into text. ASR ensures that the auditory input is transformed into a structured, machine-readable format, which is essential for downstream NLP tasks. Libraries or APIs like Google Speech-to-Text or similar technologies can be employed for this purpose, ensuring high accuracy in transcription. Once

the speech is converted to text, Natural Language Processing (NLP) techniques are applied to process the query further. NLP methods handle noise in the data, refine the text by tokenization, and prepare it for embedding generation. This text is then passed through Sentence-BERT (SBERT), a deep learning model designed to generate dense vector representations (embeddings) of text. These embeddings encapsulate the semantic meaning of the query, enabling the system to compare and match it effectively with relevant content in the answer repository.

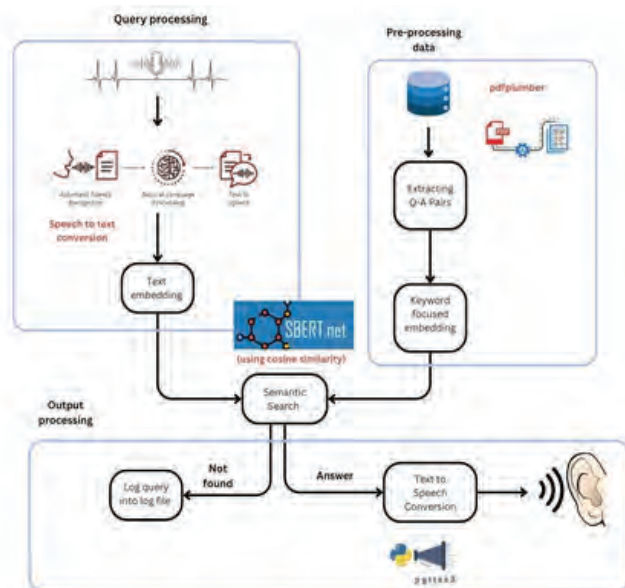


Fig. 2 System Design of Voice Automated Chatbot

Data Pre-Processing

To ensure efficient retrieval of relevant answers, the input data repository undergoes a detailed pre-processing stage. This stage focuses on preparing a comprehensive database of question-answer (Q-A) pairs. Using pdfplumber, the system extracts Q-A pairs from structured or semi-structured PDF documents. This tool is particularly effective for parsing text from documents with complex layouts, ensuring that no crucial data is missed. Once extracted, the Q-A pairs are pre-processed for embedding generation. Each Q-A pair is converted into a vector representation using the Sentence-BERT (SBERT) model. This embedding step focuses on capturing the semantic meaning of the text, with an emphasis on keywords to improve the system's ability to identify relevant responses. These embeddings are stored and indexed, creating a searchable repository optimized for semantic similarity computations.

Semantic Search and Matching

The semantic search component is the heart of the system. When a user query is embedded, it is compared with the pre-processed embeddings of Q-A pairs using cosine similarity, a metric that quantifies the semantic closeness between two vectors. This ensures that the system retrieves the answer most closely aligned with the meaning of the user's query, rather than relying solely on keyword matching. By leveraging SBERT's high-quality embeddings and cosine similarity, the system can effectively handle diverse query structures, including paraphrased or contextually nuanced inputs. If no suitable match is found (i.e., if the similarity score falls below a predefined threshold), the query is logged into a log file for further analysis. Logging unmatched queries helps identify potential gaps in the repository or limitations in the model's coverage, supporting iterative improvements to the system.

Output Processing

Once the best-matched answer is retrieved, it is converted into audible speech using a text-to-speech (TTS) engine, such as pyttsx3. This step ensures the system delivers responses in a format accessible to users, particularly in hands-free or accessibility-focused applications. The TTS engine synthesizes the text output into natural-sounding speech, which is then played back to the user. In cases where no matching answer is found, the system logs the user query for future enhancements and notifies the user about the absence of a relevant response, maintaining transparency.

TECHNOLOGIES

To achieve the research objectives and build an efficient, user-centric query-answering system, several state-of-the-art technologies were employed. Each component plays a critical role in enabling seamless processing, retrieval, and delivery of information. The following is a detailed explanation of the technologies used:

Automatic Speech Recognition

Automatic Speech Recognition (ASR) is a transformative technology that converts spoken language into written text, enabling seamless interaction between humans and machines. Initially relying on statistical methods such as Hidden Markov Models (HMMs) and Gaussian Mixture Models (GMMs), ASR has undergone significant advancements with the emergence of deep learning.[10] Modern systems utilize architectures like Recurrent Neural Networks (RNNs), Long Short-Term Memory networks (LSTMs), and Transformers to achieve improved accuracy and adaptability. Despite its progress, ASR faces challenges such as handling diverse accents, dialects, background noise, and code-switching scenarios. End-to-end learning models have simplified workflows, while large-scale datasets and pre-training

techniques have enhanced system generalization. ASR finds applications in voice assistants, accessibility tools, and transcription services, revolutionizing industries like healthcare, education, and legal services.

Natural Language Processing

Natural Language Processing (NLP) is a specialized field of Artificial Intelligence and Linguistics that focuses on enabling machines to understand, interpret, and generate human language. It is essential for facilitating human-computer interaction in natural languages, bridging the gap for users who may not be familiar with machine-specific languages.[9] NLP techniques are employed to refine and process the text obtained from the ASR system. This includes tasks such as tokenization, cleaning, and preparing the text for embedding generation. By addressing linguistic nuances such as synonyms, grammatical variations, and contextual meanings, NLP ensures that the system can interpret user queries effectively. Advanced NLP models, such as Sentence-BERT (SBERT), are used downstream to represent text in a semantic embedding space. These techniques allow the system to focus on meaning rather than syntax, making it resilient to diverse query phrasing.

pdfplumber

For creating the repository of possible answers, this research uses pdfplumber, a Python library designed for extracting structured and semi-structured text from PDF documents. pdfplumber is highly effective for parsing complex layouts, such as tables, headings, and multi-column text, which are often present in Q&A datasets. By extracting relevant question-answer pairs from large, unstructured documents, pdfplumber helps automate the pre-processing phase, saving significant time and ensuring the accuracy of the input data. SBERT is a cutting-edge deep learning model designed to generate high-quality semantic embeddings for text data. It is based on the BERT (Bidirectional Encoder Representations from Transformers) architecture but optimized for sentence-level tasks. SBERT converts both the user query and the repository question-answer pairs into dense vector representations that encode their semantic meaning. This technology enables the system to perform semantic search by comparing the embeddings, allowing it to retrieve contextually relevant answers even when the query phrasing differs from the phrasing in the dataset.

SBERT

In our project, SBERT (Sentence-BERT) is utilized to address the challenge of handling a question-answering database where the same question can be asked in multiple ways. SBERT is chosen because it excels at generating high-quality

semantic embeddings that capture the contextual meaning of sentences, enabling the system to understand the intent behind diverse phrasings. To identify the most relevant answer for a given query, cosine similarity is employed as the metric for comparing text embeddings generated by SBERT. Cosine similarity calculates the angle between two vectors in a high-dimensional space, providing a measure of their semantic closeness. By ranking the similarity scores, the system can determine the answer most closely aligned with the user's query. This metric ensures that responses are retrieved based on meaning rather than exact word matches, significantly improving the system's robustness and accuracy. The use of SBERT enhances the project's ability to handle linguistic variations effectively, delivering precise and meaningful answers regardless of how the question is framed.

pyttsx3

pyttsx3 is a text-to-speech (TTS) conversion library used to synthesize human-like speech from textual data. This technology enables the system to deliver auditory responses to user queries, making it highly interactive and accessible, particularly for users with visual impairments or those operating in hands-free environments. pyttsx3 provides a flexible, offline solution for TTS, with support for customizable voices, languages, and speaking rates. It ensures that the output is both intelligible and user-friendly, enhancing the overall system experience.

RESULTS & ANALYSIS

The proposed system was evaluated using a dataset of over 150 user queries, designed to simulate real-world scenarios where users seek answers through spoken queries. The system achieved an overall accuracy of 85%, which indicates its robustness in processing spoken inputs, retrieving relevant answers, and delivering them in a user-friendly auditory format. The 85% of queries that were answered correctly demonstrate the system's strength in leveraging ASR, semantic embeddings, and cosine similarity for question-answer matching. The system performed well in cases where:

- The query was phrased similarly to the question-answer pairs in the repository.
- Semantic relationships between the query and the repository data were straightforward, such as synonyms or paraphrases.
- The repository contained detailed and structured data on the query topic.

These observations validate the efficacy of Sentence-BERT embeddings in capturing semantic meaning and the effectiveness of cosine similarity as a matching mechanism.

However, the 15% of incorrect responses highlighted several areas for improvement, which are categorized and analysed below.

Absence of Data in the Repository

A significant proportion of incorrect responses occurred because the system lacked relevant information for certain queries in the repository. In such cases, the system accurately logged the query and provided no response, as it could not find a matching answer with sufficient semantic relevance. This limitation emphasizes the critical role of a comprehensive and well-maintained database. Without sufficient coverage of possible topics, the system's ability to answer user queries will remain constrained. Expanding the repository to include broader and more diverse question-answer pairs, as well as continuously updating it with new data, is essential to improving accuracy in future iterations.

Low Confidence Scores (<0.5)

Another limitation was the system's inability to confidently retrieve an answer for some queries, even when related data was present in the repository. In such cases, the semantic similarity score—calculated using cosine similarity between the query and the answer embeddings—fell below the threshold of 0.5, causing the system to discard the potential response. This issue suggests that the Sentence-BERT embeddings might require fine-tuning or additional contextual training to better capture subtle nuances in certain types of queries. Moreover, adjusting the confidence threshold dynamically based on the query type or introducing an ensemble scoring mechanism could help the system better handle borderline cases.

Challenges with Comparative or Contextual Queries

For queries involving comparisons or requiring contextual reasoning (e.g., “Which product is better, X or Y?”), the system struggled to provide relevant answers, even when the repository contained related data. This limitation arises because the current implementation focuses on matching semantic embeddings but lacks the ability to perform logical reasoning or context-specific analysis. For example, if the repository contains details about both products X and Y, the system still fails to compare their attributes effectively. Addressing this challenge will require incorporating additional reasoning capabilities, such as:

- Building context-aware embeddings that can model relationships between entities within a query.
- Implementing specialized comparison algorithms that identify and rank attributes relevant to the query context.
- Integrating knowledge graphs to provide richer connections between entities and enhance query

understanding.

The evaluation results underline the system's potential as an effective spoken query-answering tool. With 85% accuracy, the system demonstrates its ability to handle most straightforward and semantically aligned queries. However, the remaining 15% of incorrect responses reveal opportunities for further refinement in database expansion, embedding quality, and reasoning capabilities. By addressing these limitations, the system can evolve into a more comprehensive and intelligent solution for spoken information retrieval.

CONCLUSION

The “Admission Assistant Robot” demonstrates the transformative potential of voice-automated AI systems in streamlining administrative processes in educational institutions. By leveraging technologies such as Automatic Speech Recognition (ASR), Natural Language Processing (NLP), and semantic search, the system effectively addresses challenges associated with handling large volumes of admission-related queries. With an overall accuracy of 85%, the chatbot has proven to significantly reduce response times, improve accessibility, and enhance the user experience by automating repetitive tasks. The research highlights the scalability and reliability of the system, which can handle up to 1,000 queries daily with consistent accuracy. Furthermore, the study underscores the importance of a well-maintained repository and continuous updates to address limitations in handling complex or comparative queries. Future work can focus on integrating advanced reasoning capabilities and expanding data coverage to further enhance the system's accuracy and versatility. This study establishes the Admission Assistant Robot as a valuable tool for educational institutions, providing a framework that can be extended to career counselling centres and other domains, paving the way for improved efficiency and user satisfaction through AI-driven solutions.

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QR Based Attendance Tracking

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ABSTRACT

Attendance tracking is essential for monitoring participation, ensuring accountability, and maintaining accurate records in workplaces, schools, events, or group activities. Scenarios include employee time tracking, student attendance in classrooms, participant check-ins at conferences, and volunteer monitoring for community projects. QR makes the process of attendance easier and smarter. By scanning QR code attendance is directly marked in the database within a second. It reduces the work of teacher, volunteers. Our system is an easy-to-use QR code-based attendance tracking tool designed to simplify managing attendance. Users can quickly scan unique QR codes (which will be given on the website by smartphones) with the ESP32 Cam module to mark attendance instantly and accurately. The system offers real-time updates for attendance details including the date, time, name, enrollment number in the database. Its secure design makes it suitable for organizations of all sizes, ensuring smooth and reliable attendance tracking. This system makes the attendance tracking smarter, less time consuming, efficient, and real-time attendance. It reduce the errors, proxies which occur while taking attendance traditionally. This system is used in educational institutions, corporate organizations, and events, etc

KEYWORDS : QR Code, Attendance tracking system, Attendance management.

INTRODUCTION

Attendance tracking is essential for maintaining accountability across various scenarios, including academic institutions, corporate events, and public gatherings. Traditional methods such as manual roll calls or online forms are often time-consuming and prone to human error. Biometric systems, while more advanced, can be expensive and have potential privacy concerns. Additionally, managing attendance efficiently in hybrid environments, where some participants are remote, poses unique challenges. These issues underscore the need for innovative solutions that are both efficient and scalable.

A QR code (Quick Response code) is a two-dimensional barcode that stores information in the form of black and white squares arranged on a grid. This information is encoded using error correction algorithms to ensure readability even when the code is partially damaged. QR codes are generated through software libraries or APIs, which translate input data (e.g., user ID or event details) into a scannable code. They are widely used due to their simplicity and reliability.

In attendance systems, QR codes are typically scanned using cameras or specialized hardware, such as an ESP32-CAM module, to retrieve and log data into a central database.

Alternative digital methods for attendance tracking include RFID tags, NFC-enabled devices, and biometric systems like fingerprint or facial recognition. While RFID and NFC offer contactless scanning, they often require costly specialized hardware. Biometric systems are accurate but raise concerns regarding privacy and potential misuse of sensitive data. Smartphone-based GPS tracking, though innovative, can face technical challenges such as location spoofing and network dependency, reducing reliability. These limitations restrict their adoption in certain environments.

The use of QR codes overcomes many of the limitations associated with other digital methods. They are cost-effective, easy to generate, and require minimal infrastructure, making them suitable for diverse use cases. QR codes also prevent privacy concerns since they do not store sensitive biometric data. Additionally, they can be integrated into existing systems for real-time synchronization and monitoring,

ensuring accuracy and security, particularly when combined with identity verification methods.

This paper is organized as follows: Section II presents the methodology for implementing the QR-based attendance system, including hardware and software integration. Section III discusses the system design, highlighting its architecture and use cases. Section IV evaluates the system's performance, emphasizing its advantages over traditional methods. Section V concludes the study, summarizing findings and proposing potential future improvements to the system

LITERATURE SURVEY

[1] Xiong Wei et al. - QR Code-Based Smart Attendance System

This study introduces a smartphone-based system where teachers scan QR codes containing student details to mark attendance. The data is recorded as binary (1 for present, 0 for absent) and can be exported in CSV or XLS formats. The system aims to enhance accuracy and reduce the chances of fake attendance by ensuring that each QR code is unique to the student. This paper provided us insights into reducing fake attendance.

Keywords: QR, Attendance, System, Professor, Student.

[2] Arpankumar Patel et al. - Smart Student Attendance System Using QR Code (SSRN)

This paper emphasizes the convenience and security of using QR codes for attendance. Teachers display a QR code, and students scan it with their smartphones to mark their presence. Identity verification techniques are used to prevent fake registrations. The system highlights the capability of QR codes to store large amounts of information, offering an efficient solution for modern classrooms. This paper enabled us to understand the storage capacity of a QR code and format the data to meet the requirements.

Keywords: Mobile Computing, Database, Attendance System.

[3] Shubham Mishra et al. - Online Attendance Monitoring System Using QR Code (IEEE Xplore)

The SAMSTM system, developed at Universiti Kebangsaan Malaysia, automated attendance tracking using smartphones or tablets to scan QR codes. Its main advantages are reduced manual workload and enhanced accuracy in large classrooms. Initial trials suggest positive feedback, with the potential for cross-platform support in the future. It gave us insights into

methods to reduce the manual work involved during the attendance taking process.

Keywords: Attendance, QR Code, Mobile Devices, Automation.

[4] A. A. Abd. Rahni et al. - Development of SAMSTM Based on QR Codes and Mobile Devices (JESTEC)

Building on the SAMSTM framework, this study focuses on the operational setup and user feedback. It demonstrates how automated attendance systems can predict academic performance through consistent monitoring. The study also discusses commercial potential and broader adoption in educational institutions. This enabled us to understand how to make the attendance data more valuable to the management team.

Keywords: Online, Attendance, Monitoring, Mobile Devices.

[5] T. Jamil - Automatic Attendance Recording System Using Mobile Phones (TELFOR)

Although not QR-based, this paper presents an innovative mobile attendance system using Bluetooth to detect students' devices via MAC addresses. This approach provides an alternative to QR codes by leveraging mobile phone connectivity for attendance tracking. This paper provided us insights to reducing proxy attendance through the Bluetooth address of devices.

Keywords: Mobile Phones, Bluetooth, MAC Address, Paperless.

[6] Fadi Masalha & Nael Hirzallah - A Student Attendance System Using QR Code (IJACSA)

This study addresses the growing use of smartphones in educational environments and proposes a QR code-based attendance system for university lectures. The system improves the efficiency of attendance tracking by verifying student identities and preventing false registrations, contributing to a more streamlined educational process. In conjunction with the previous paper, this enabled us to reduce false attendance records in addition to using the smartphone to bring down costs of implementation of our system.

Keywords: QR Code, Smartphone, Identity Verification, University Attendance.

[7] Henry Dietz, Dillon Abney, Paul Eberhart, Nick Santini, William Davis, Elisabeth Wilson, Michael McKenzie -

ESP32-CAM as a programmable camera research platform (Society for Imaging Science and Technology)

This paper explores using the ESP32 CAM module across three different projects, showcasing its versatility as a

programmable camera board. Through these implementations, we were able to understand the module's performance in different environments, this enabled us to develop a system which is capable of operating efficiently across various conditions

Table 1 Comparative Analysis of Literature

Author	System Focus	Technology Used	Key Features	Advantages	Limitations
Xiong Wei et al.	QR code-based smart attendance system	QR Codes, Smartphone	Teachers scan QR codes to mark attendance, exportable data in CSV/XLS formats.	Accurate, reduces fake attendance, and unique QR codes.	Requires teacher interaction for scanning QR codes.
Arpankumar Patel et al.	Smart student attendance system	QR Codes, Smartphone	Students scan QR codes displayed by teachers; identity verification to prevent fake entries.	Convenient, secure, supports large data storage.	Relies on student device functionality and QR scanning.
Shubham Mishra et al.	Online attendance monitoring using QR codes	QR Codes, Mobile Devices	SAMSTM system automates attendance with cross-platform support potential.	Reduces workload, high accuracy, positive user feedback.	Initial trials only; further optimization needed.
A. A. Abd. Rahni et al.	SAMSTM framework for automated attendance	QR Codes, Mobile Devices	Predicts academic performance, discusses commercial potential and adoption scalability.	Consistent monitoring, user feedback-driven design.	Focuses mainly on educational use, limits adaptability.
T. Jamil	Mobile-based automatic attendance	Bluetooth, MAC Address, Smartphones	Uses Bluetooth to detect devices via MAC addresses as an alternative to QR codes.	Contactless, innovative use of device connectivity.	Not QR-based; requires Bluetooth-enabled devices.
Fadi Masalha & Nael Hirzallah	QR code-based student attendance system	QR Codes, Smartphones	Verifies identity, prevents false registrations, and streamlines educational processes.	Efficient, reliable, prevents fake attendance.	Requires integration of identity verification tools.
Henry Dietz, Dillon Abney, Paul Eberhart, Nick Santini, William	Performance of ESP32 Cam Module	ESP32 Cam Module	2 MP Camera, Dual Core Processor, Wireless Connectivity, Low Cost, Programmable	Cost Effective, Affordable, High Programmability, Connectivity, & Flexibility	Lower Image Resolution, Limited Processing Capability & Physical Constraints

METHODOLOGY

Our research focuses on developing an attendance monitoring system by utilizing QR codes to simplify the process while reducing the errors caused by the manual process or by technologies such as RFID. We prioritized achieving cost-effectiveness, user-friendliness, and higher accuracy while also providing the organizers to visualize the received data

Hardware Module

This circuit diagram illustrated in Figure 1 consists of an ESP32-CAM module, with a micro USB type A breakout board with its power pins connected to the 5v and GND pins of the ESP32 CAM module. We can also power it using a

3.7v battery connected to the module via a BMS [Battery Management System], and a buck boost converter to regulate the voltage. This can be then connected to the aforementioned pins on the board or the 3.3v input pin depending on the buck boost converter chosen.

Software Module

During signup, the attendee enters their details which are stored in a Supabase database via an API request. When they try to log in, the system checks if they exist in the database. If they don't, they are asked to complete the signup process but if their records exist within the database a unique QR code is generated containing their enrollment number and timestamp. At the event, the ESP32-CAM Module scans the

QR code, and the system verifies the user again by checking the database; if the user exists, their attendance is stored in the database; if not, an error is displayed. This ensures only registered attendees can mark their attendance, the entire aforementioned process is illustrated via the block diagram in Figure 2.

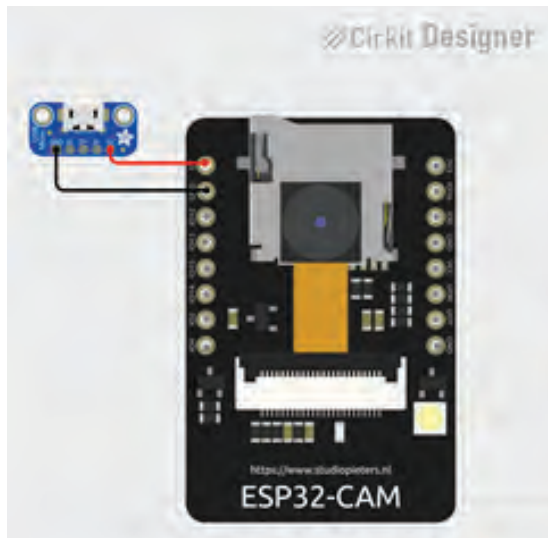


Fig. 1 Circuit Diagram

Enclosure

We used Fusion 360 to design a basic enclosure that provided sufficient space to house the board, along with a Micro USB Type-A board or battery along with the required regulation and charging circuit as seen in Figure 3. The design was then exported into slicing software, where we configured the printer type, nozzle, and filament settings. The GCode was uploaded to an SD card, and the design was printed using a Creality Ender 3v2 printer with Creatility PLA filament. The entire printing process took 3 hours after which we assembled the hardware and put it into the enclosure.



Fig. 3 Model of Enclosure

RESULTS & EVALUATION

Web Interface

The attendee registration page allows a new user to create his own account using email address and password as shown in Figure 4.

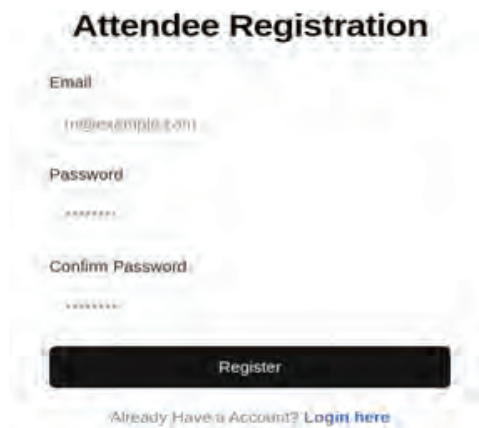


Fig. 4 Attendance Registration Page

The login page shown in Figure 5, allows the attendees, management team and admins to login to their respective dashboards based on their roles.

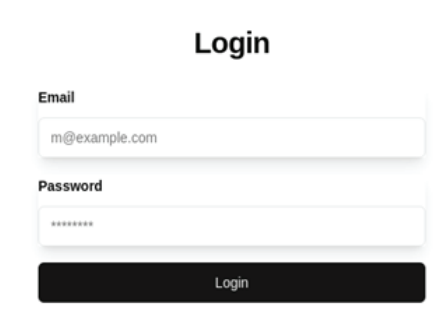


Fig. 5 Login Page

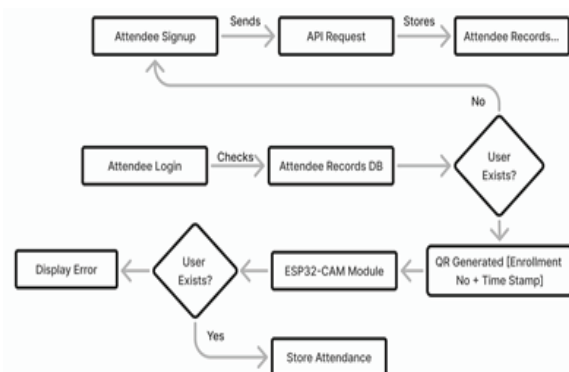


Fig. 2 Block Diagram

Figure 6 illustrates the dashboard for an attendee which shows their unique QR code, this is then scanned using the camera module to mark their attendance for the event. The profile section takes in the further details required for the generation of the QR code which include their name and enrolment number.



Fig. 6 Attendance Dashboard

The management dashboard as shown in Figure 7 allows the members of the management team to view the attendance for a particular event along with the relevant details associated with the user. The members of the management team can only signup using the credentials provided by admin to ensure security and privacy of the attendees. Their profile section allows them to enter their personal details such as their name and phone number which can be viewed by the admin for future records.

Management Dashboard			
My Profile Calendar			
Sr. No	Name	Date	Time
1	David Zachariah	12/1/2024	05:34 PM
2	David Zachariah	12/1/2024	05:53 PM
3	David Zachariah	12/1/2024	06:00 PM
4	David Zachariah	12/3/2024	09:42 AM
5	David Zachariah	12/3/2024	09:43 AM
6	David Zachariah	12/3/2024	10:47 AM

Fig. 7 Management Dashboard

The admin dashboard shown in Figure 8 allows an admin to view the details of the users registered onto the platform which includes the members of the management team and

the attendees which can be used for future records. It also grants them the ability to create accounts for the members of the management team along with the ability to add profile details such as their name and phone number. To add a layer of security we have added a 2 minute timeout to prevent any malicious activity.

Admin Dashboard

My Profile Add User		
Management		
Name	Email	Phone Number
David Zachariah	davezaxh@gmail.com	986045192369
Kashmira Deokar	kashmiradeokar937@gmail.com	12345678910
atharv maind	atharvmaind05@gmail.com	51234897869

Fig. 8 Admin Dashboard

Hardware Module

The hardware module shown in Figure 9 consists of the ESP32 CAM module within the 3D printed enclosure with additional space to house the components to power the device.



Fig. 9 ESP32 Cam with 3D Enclosure

Working

The attendee signs up using the web application using his email address along with a password, then they proceed to add their primary details such as their name and enrolment number which are used to generate a QR code unique to the user along with the current timestamp to reduce the cases of proxy attendance. This QR is scanned using the ESP32-

CAM module and then stored within the assigned table, these records can be viewed by the management team to view the attendance for the given event along with the relevant details.

Findings

Based on our research, we found out that there was a reduction in workload for the organizers gathering attendance. However, there was a need for a member to manage the device in case of any hardware failures. We gathered the following findings during the usage of the ESP32 CAM module:

1. When it was running on a 3.7V 250mAh battery along with a buck converter to step down and provide a stable voltage. It operated smoothly for approximately 1-1.2 hours before it stopped working while it ran without any limitations when directly connected to a power source via the micro USB Type-A connector.
2. It takes an average 2-3 seconds for the module to scan the QR codes in a well lit room.
3. In a network with less congestion, and the proximity of the access point placed within 5 meters of the module it takes 100-200 ms to insert the data into the table, in a congested network such as college networks, it takes 300-400 ms to insert the same data.
4. We identified certain cases of proxy attendance, which was mitigated due to organizers monitoring the hardware module.

The QR-based attendance tracking system offers a significant improvement over traditional methods, providing a more

efficient, secure, and cost-effective solution. By utilizing QR codes, the system eliminates common issues such as human error and time delays associated with manual roll calls or online forms. The integration of the ESP32-CAM module for scanning QR codes allows for real-time data synchronization with a centralized database, ensuring accurate attendance records while being cost effective. Compared to alternatives like RFID, NFC, and biometric systems, QR codes present a simpler, privacy-conscious option that minimizes hardware costs while maintaining reliability. Despite some challenges, such as potential proxy attendance, the system demonstrates clear advantages, particularly in large-scale or hybrid environments, where its ease of use and scalability become key strengths.

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ABSTRACT

The National Education Policy (NEP) 2020, introduced by the Government of India, holds the potential to reshape the entire educational landscape of the country, including diploma education. The policy focuses on holistic, outcome-based education, interdisciplinary learning, and the integration of skill development. This paper explores the current state of diploma education in India and how its transformation under NEP 2020 could contribute to producing versatile, industry-ready graduates, including fostering entrepreneurship. The paper also evaluates the long-term economic impact of these reforms, considering India's demographic advantage and the growing demand for skilled workers and entrepreneurs.

KEYWORDS : : NEP, OBE, AI, ML, IoT.

INTRODUCTION

Diploma education in India plays a crucial role in providing students with industry-specific skills and enabling them to enter the workforce quickly. It traditionally caters to technical, vocational, and skill-based training, focusing on areas such as engineering, nursing, hospitality, and information technology. However, the current structure faces several challenges, including a rigid curriculum, insufficient focus on entrepreneurship, and limited alignment with the evolving needs of the labor market.

The National Education Policy (NEP) 2020 aims to address these shortcomings by fostering a more flexible, holistic, and outcome-based education system. With a focus on skill development, multidisciplinary learning, and the integration of vocational education, the NEP offers an opportunity to transform diploma education. Moreover, it emphasizes entrepreneurship and aims to create a skilled workforce capable of contributing to India's economic growth. This paper examines the implications of NEP 2020 on diploma education, the production of versatile graduates, the nurturing of entrepreneurship, and the expected economic outcomes.

CURRENT STATE OF DIPLOMA EDUCATION IN INDIA

Diploma programs in India primarily aim to equip students with technical and vocational skills, which prepare them for specific career paths. These programs are generally shorter in duration (2-3 years) and provide specialized training in sectors like engineering, healthcare, business administration, and information technology. However, several issues persist:

1. **Limited Scope of Curriculum:** Diploma programs are often narrowly focused on technical skills, with insufficient emphasis on cross-disciplinary knowledge or soft skills like communication, leadership, and critical thinking.
2. **Lack of Flexibility:** Traditional diploma education offers limited opportunities for students to explore diverse fields or switch academic tracks after enrolment, restricting students' ability to adapt to changing career landscapes.

3. **Industry Alignment:** While diploma courses are designed to address industry needs, rapid advancements in technology and the changing nature of work have resulted in skill gaps between what is taught and what employers require.
4. **Equity and Access:** Diploma education is concentrated in urban areas, limiting access for students in rural or economically disadvantaged regions.
6. **Flexibility and Multiple Pathways:** The NEP promotes flexible education systems that allow students to move between different levels of education, including moving from vocational courses to higher education, creating a system of credit transfer and recognition.
7. **Equity and Inclusion:** The policy focuses on increasing access to education for all segments of society, especially marginalized and rural communities. This includes promoting vocational and diploma education in underrepresented areas.

THE NATIONAL EDUCATION POLICY (NEP) 2020: KEY PROVISIONS RELEVANT TO DIPLOMA EDUCATION

The NEP 2020 offers several provisions that directly affect the future of diploma education:

1. **Holistic and Multidisciplinary Education:** NEP 2020 shifts from rigid, discipline-specific programs to more flexible, interdisciplinary learning. Diploma courses will likely offer students opportunities to explore multiple fields, promoting the development of well-rounded, versatile graduates.
2. **Focus on Vocational Education and Skill Development:** The NEP emphasizes the integration of vocational education into the mainstream curriculum at all levels, including the school level. By 2025, at least 50% of students are expected to have access to vocational education, which will create seamless pathways from school to diploma programs.
3. **Outcome-Based Education (OBE):** The policy advocates for a shift toward outcome-based learning. This system ensures that the focus is on the competencies, skills, and knowledge that students acquire, rather than the traditional focus on inputs like classroom hours and examinations.
4. **Entrepreneurship and Innovation:** NEP 2020 encourages the creation of an entrepreneurial mindset among students. Through the integration of entrepreneurship courses, practical projects, and innovation hubs, diploma programs can play a key role in fostering future entrepreneurs.
5. **Technology and Digital Integration:** The NEP stresses the integration of technology in education. This includes the use of online platforms for learning, virtual labs, and the incorporation of emerging technologies like artificial intelligence (AI), machine learning (ML), and the Internet of Things (IoT) into diploma curricula.

TRANSFORMATIONS IN DIPLOMA EDUCATION POST-NEP IMPLEMENTATION

Producing Versatile Graduates

One of the major benefits of NEP 2020 is its emphasis on multidisciplinary education, which will enable diploma students to become more versatile and adaptable in their careers. Under the current system, students often graduate with specialized, technical skills but limited exposure to other fields. The NEP envisions a system where students are encouraged to combine technical training with knowledge from other domains—such as humanities, social sciences, or business management—thereby enhancing their critical thinking, problem-solving, and decision-making abilities.

For example, a student pursuing a diploma in electrical engineering could also take courses in design thinking, business management, or digital marketing. This broadens their skill set and opens up opportunities in diverse sectors such as project management, innovation, and leadership roles. This versatility will make graduates more attractive to employers and better equipped to adapt to a rapidly changing workforce.

Fostering Entrepreneurship

Entrepreneurship is a key focus of the NEP 2020. The policy aims to foster an entrepreneurial culture from an early stage by integrating entrepreneurship education into school curricula and higher education. This approach is expected to extend to diploma programs as well, with an emphasis on encouraging students to develop entrepreneurial skills such as innovation, creativity, and business acumen.

Diploma students, who typically enter the workforce quickly, can be instrumental in driving India's entrepreneurial ecosystem. NEP 2020's proposal to set up incubation centres and innovation hubs within educational institutions will provide aspiring entrepreneurs with the resources and support they need to turn their ideas into viable businesses.

Additionally, through experiential learning and real-world projects, diploma students will gain the practical knowledge needed to start their ventures, creating a more robust startup culture.

Impact on the Economy

The NEP's reforms are likely to have a significant impact on India's economy by contributing to the development of a skilled, versatile, and entrepreneurial workforce. India's demographic advantage—its large, young population—presents an opportunity for economic growth, but only if the education system can produce graduates with the right skills.

1. **Skilled Workforce:** By focusing on skill development and vocational education, the NEP aims to bridge the skill gap and create a workforce that is better equipped to meet the demands of a rapidly evolving job market. This could lead to higher productivity, reduced unemployment, and a more competitive economy.
2. **Job Creation through Entrepreneurship:** The policy's focus on entrepreneurship could stimulate job creation, as more diploma graduates venture into the startup ecosystem. India's thriving tech and service sectors could see an influx of new businesses, contributing to economic diversification.
3. **Economic Inclusivity:** By increasing access to education in rural areas and among marginalized communities, the NEP could help to reduce regional disparities in employment opportunities. As diploma programs expand and evolve, they will provide a pathway to economic inclusion, enabling students from all backgrounds to participate in India's growth story.
4. **Global Competitiveness:** With a more globally competitive workforce, India could increase its presence in international markets, attracting foreign investments and contributing to the country's integration into global supply chains.

WILL THE NEP MAKE DIPLOMA EDUCATION MORE BENEFICIAL AND OUTCOME-BASED?

The NEP 2020's emphasis on outcome-based education and vocational training is likely to transform diploma education into a more practical, results-driven system. By aligning diploma programs with the needs of industry and focusing on developing a wide range of competencies, the NEP has the potential to make students not just job-ready but also adaptable to future career changes.

The integration of entrepreneurship and innovation into the curriculum will ensure that students are not only equipped with technical skills but also with the mindset needed to create and lead businesses. As a result, the NEP could contribute to a new generation of entrepreneurs who will drive India's economy forward.

Moreover, the flexibility introduced by the NEP will allow students to explore different career pathways, making diploma education a more dynamic and versatile option. The inclusion of technology and digital learning platforms will also ensure that diploma graduates have the skills to thrive in an increasingly digital world.

CONCLUSION

The National Education Policy (NEP) 2020 holds transformative potential for diploma education in India. Through its emphasis on holistic, multidisciplinary education, vocational training, and entrepreneurship, the NEP aims to produce a more versatile, adaptable, and industry-ready workforce. The focus on entrepreneurship could significantly contribute to India's startup ecosystem, creating job opportunities and driving economic growth. If implemented effectively, these reforms will create a skilled and dynamic workforce that can meet the challenges of the future and contribute to India's economic success on a global scale.

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Measuring the Impact of Technical Debt on Development Effort in Software Projects

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ABSTRACT

Technical debt refers to the trade-offs between code quality and faster delivery, impacting future development with increased complexity, bugs, and costs. This study empirically analyzes the additional work effort caused by technical debt in software projects, focusing on feature implementations. I explore how delaying technical debt repayment through refactoring influences long-term work effort. Using data from open-source and enterprise projects, I correlate technical debt with practical work effort, drawing from issue trackers and version control systems. Our goal is to provide a framework for managing technical debt, aiding developers, project managers, and stakeholders in understanding and mitigating its impact on productivity and costs.

INTRODUCTION

First proposed the metaphor of technical debt Cunningham [1993], in reference to the temporary sacrifice of code quality in exchange for faster delivery of features. Thus, incurring technical debt might be useful to achieve immediate deadlines but may simultaneously have negative consequences for the future work, such as software complexity growth, the prevalence of bugs and defects, decreased team productivity and augmented work effort, leading to increased costs of development, infrastructure, and management. The impact of this technical debt may affect the daily work of developers, project managers, product owners and other business stakeholders.

Although initially intended as a metaphor, considerable research has since been undertaken into the identification [1], measurement [2], and management [3] of technical debt. Research has also expanded the scope of the term, such that technical debt spans not just activities related to code implementation but the entire software development environment [4]. The research community identified multiple types of debts [5], each with its advantages and consequences if not handled accordingly. Although industry practitioners are aware of its presence [3] [1], there is no standard way of measuring the current and future impact of technical debt on the development and costs of the team. Additionally, due to a lack of vocabulary and the complexities of the phenomenon, developers find it difficult to convey their concerns to project stakeholders [6].

For example, code smells are an example of technical debt items that may increase future development effort and maintenance costs [7]. Industry case studies have shown that such code violations are more likely to be addressed if made visible by developers within the project's issue tracker [1]. However, from the perspective of a project manager, it is essential to understand how much effort the team puts into technical debt reduction activities and if there is an associated business value. A key concern, therefore, is the ability to measure and make rationale cost-benefit analyses of the impact of technical debt on productivity within a project, capturing both the principal debt incurred and consequent interest as poor code quality accumulates.

The primary research objective of our work is to identify the accumulated additional work effort caused by the presence of technical debt in a code base through an empirical analysis of the work effort of feature implementations within software projects. I intend to determine whether a decision to delay repaying technical debt through refactoring work creates additional work effort in the longer term to repay that debt. I.e., does technical debt really incur interest to the principal, and if so, in what way? An additional objective is to understand how the measure of technical debt varies with software evolution and what types of features incur or reduce its presence. The research questions for our work, organised using the Goal- Question-Metric approach [8], are as follows:

- RQ1. Can technical debt be measured in the context of work Effort?

- RQ1.1. How does the work effort cost of feature implementation vary with the magnitude of technical debt?
- RQ1.2. Does technical debt incur interest in terms of increasing work effort cost of feature implementation as removal of technical debt items are delayed?
- RQ2: What are the development patterns surrounding the feature lifecycle?
 - RQ2.1: At what checkpoints in feature development is technical debt reduction (refactoring) most prominent?
 - RQ2.2: What type of work items incur the most technical debt?

I intend to adopt an empirical approach to the identification of the impact of technical debt on the implementation of future features in existing software code bases. To do this, I will calculate the level of technical debt in the system for each change-set recorded in a project's version control repository. I will also record and calculate the practical work effort spent on feature implementation linking data from a project's issue tracker and version control repository, thus estimating the effort a developer spent on completing a feature. The impact of technical debt on work effort will then be calculated by comparing the practical work effort with both the estimated effort for an issue.

As data candidates, the study will use both open-source and enterprise projects in order to understand the differences between the two worlds in the context of technical debt work effort. A large Fortune 500 institution has agreed to collaborate with us by granting access to their software development environment data. The candidates will be selected according to various criteria, such as feature development model, type of version control system, availability of estimated work effort metadata, and suitability of code quality tools.

Our long-term goal is to provide a decision-making framework for the management of technical debt in software projects. This framework may provide essential historical information that might be useful for all roles within the software development environment. For example, individual developers could find out how much extra effort was spent in areas with a high number of technical debt items. Architects could identify architectural bottlenecks quickly, while project managers would assign work based on empirical evidence gathered from past work efforts. As of January 2018, the study is in its initial stages.

The rest of this paper is structured as follows. In Section II, I contrast our study with others and how I build upon current research. Section III highlights the proposed work followed

by its limitations in Section IV and Section V summarises the proposal.

RELATED WORK

A number of studies have investigated the impact of technical debt items on the costs of software projects. This section reviews this work and relates the existing state of the art to our proposed experiment to empirically measure the work effort interest accumulated by technical debt.

Olbrich et al. [9] studied the impact of two code smells, God class and Shotgun Surgery, on change-proneness of class entities and size of changes within two open source systems, Apache Lucene and Apache Xerces. They found that classes containing either smell are more change-prone than other, non-smelly classes. In a similar study, Khomh et al. [10] empirically analysed the impact of 29 code smells on the change-sets of 9 releases of two open-source systems. They confirmed the results of the previous studies that code smells increase the number of changes that software undergoes during its evolution. Additionally, they found that classes containing more than one code smell are more change prone than other classes. Charalampidou et al. [11] introduced a study that assessed the interest probability of code smells, which is the probability of a code smell introducing extra changes in future development. Interest probability was calculated by counting the frequency of each code smell and how it correlated with the change-proneness of the module where it resides. The smells studied were Long Method, Conditional Complexity, and Duplicated Code. The results showed that code duplication had the highest interest probability due to the number of changes required to maintain future development. Additionally, the complexity of the cyclomatic method increased the number of changes. Fontana et al. [12] studied what was the impact of removing code smells on code quality metrics such as cohesion, coupling, and complexity and which smell incurred the most debt. They applied refactoring activities for each smell, and the metrics were re-evaluated. The results showed that refactoring of one code smell might provide benefits for some metric qualities but may negatively impact others.

The authors studied the impact of code smells and their removal on the software quality metrics output by code quality tools. Although their research has increased awareness of technical debt, our proposed work aims to focus on what impact code smells have on feature implementation by identifying code smells using automated tools. Additional studies have looked at quantifying implementation costs in the context of technical debt.

Singh et al. [13] calculated interest payments by monitoring development effort and code comprehension. They

monitored time spent by developers in classes with known technical debt items. They implemented a tool within the Integrated Development Environment of developers to gather information on class visits and development session times. The interest was quantified as the difference between time practically spent in classes and the ideal time. However, the study was conducted with the input of only one developer over nine months. Additionally, estimating the perfect time spent on development is a challenging task due to social and personal factors such as level of project knowledge, environment familiarity, and programming language preference.

Gomes et al. [14] studied the correlation between software evolution, defect occurrence, and work effort deviation at the release level. The authors extracted data from documentation sources such as test plans, project plans, weekly reports, project source code, and emails. Using this data, they could derive important team information on change sets, effort, quality, test, and size of the system. They measured extra work effort by subtracting the estimated work time and total practical work time. Although information at the release level offers project managers an idea of work effort deviation, it does not show at a granular level what defects slow down the development of a new feature and where the team should focus their refactoring activities.

The initial study by Gomes et al. [14] provided a good start to identifying work effort deviation. However, it only analyzed major releases of a system and did not provide drill-down information on iterations and code commits on which features and code smells had the most effect on the work effort. This is essential information for developers and project managers to prioritize refactoring activities in work iterations, especially in an Agile environment where responding to change is critical [15].

EXPERIMENTAL DESIGN

This study focuses on finding the relation between technical debt and work effort. This will yield more information for developers on time management, project managers on refactoring investment, and stakeholders on understanding technical concepts concerning development costs.

The approach of this study will consist of the following steps:

- 1) Identify appropriate data candidates for this study. These are potential software projects that are suitable for study. At best, they should have multiple developers contributing to the project, a medium to large codebase with a good amount of historical data, and an associated issue-tracking software. Ideally, the team would have integrated a continuous code quality tool for tracking

code smells throughout software evolution that would help with quick and automatic identification of present and historical code issues.

The study would also benefit from a mixture of open-source and enterprise software to contrast the differences between the two environments and possibly arrive at general conclusions that may contribute to both worlds.

Identify suitable work items from issue tracker.

In this step, the purpose is to understand significant events in the evolution of the data candidates. Ideally, events were tracked in the form of tickets with attached metadata, such as:

- Priority will give a sense of importance to the work item. Finding development patterns based on this field will be unique. Will developers take more time to Design and implement an important work item? Alternatively, are they pressured to deliver and thus introduce more debt in the system?
- Estimated Work Effort is one of the most important fields for calculating extra work effort. This provides the theoretical work time on which to compare the practical work time measured in this experiment. It may be in the form of work hours or a story points.
- The opening and closing timestamps of a ticket may offer valuable information for measuring the practical work effort in hours, if developers change the status of tickets as development progresses.

Unfortunately, this information is not always available. The most important field is the estimated work effort value. Without it, the extra work is difficult to identify. To mitigate this issue, I will not select feature tickets that do not contain this field.

Identify version control checkpoints

Completed work items can be tracked in the version control repository of the project. Identifying checkpoints will aid in understanding the amount of effort put into the work item by the team and how it diverges from the initial estimation.

Ideally, the team should have links between revisions of the codebase and the work item in the issue tracker. This would make it easier to find the associated checkpoints.

- 4) Measure the amount of work effort for each work item. The purpose is to understand how many practical changes a work item has induced over its lifetime. This could be done in two ways: at the code and issue tracker levels.

At the code level, it is possible to understand the level of work effort involved by aggregating the number of changes a

work item has suffered. A change set consists of the number of lines of code added, deleted, and modified. Granularity can be at the pull request, commit, class, and method levels. Version control systems such as Git provide features for retrieving change-sets between revisions.

However, identifying work effort from change-sets is a challenging task. It is difficult to quantify in working hours since many changes may be generated automatically by modern refactoring tools in the integrated development environment. An alternative solution is to compare the timestamps between the first and the last commit. The temporal difference might provide a practical estimate of the work effort to resolve the issue. Unfortunately, this case only works when a developer works on a single issue at a time.

At the ticket level, one can understand the amount of work effort realized by a team member. Ideally, the team forces developers to log the time spent designing and implementing a feature. However, that is not always the case. Alternatively, it would be interesting to retrieve the timestamp of ticket events, such as the opening and closing of an issue. Unfortunately, this might not give an approximate time of work since:

- The team does not respect the opening and closing of a ticket time according to their development patterns. For example, a developer might start work on an issue before marking it as “In Progress” and thus introduce a margin of error.
- Tickets might remain open for a long period, while features are implemented relatively quickly.
- There are differences between enterprise and open-source software. For example, developers might work in the timeframe of 9 AM to 6 PM in an enterprise while in open-source, they are free to work at any time of the day. For example, in an extreme case, a developer marks a ticket as “In Progress” before the end of the working day, and resume working the following morning. In this case, our estimation of approximately 15 hours of development time for this work item would be incorrect.

For this study, the code-level technique will be implemented. The work effort from issue tracking will be implemented in a parallel study. It will be interesting to gather results from both methods and see how they correlate. Additionally, the two result sets may complement one another and provide an overall effort metric.

Measure technical debt items

The scope of this step is to identify code violations within change sets. For each work item implemented, a set of associated modules, classes, and methods will be affected.

Historical code smells can be identified and tracked within the evolution of change sets using a continuous code quality tool.

Ideally, the team would have the code quality tool integrated into their continuous integration environment. If so, then historical code smell data could be leveraged by retrieving it through an API. Alternatively, a code quality tool will be used to analyze the version control checkpoints identified and find code smells that may have an impact on change-sets of a feature.

Analysis and discussion of results

The three data sources can be linked together once all steps are fulfilled. Extra work can be correlated to issue tracking information and code quality at the time of development. Technical debt can be classified by type, priority, code smells, and assignee.

Unfortunately, the proposed work is not as straightforward. There are many complexities of the work environment, which cannot be considered from the three data sources. Therefore, I will make some assumptions to simplify the process:

- The team uses Git for version control and follows the “Pull Request” model for implementing changes.
- Only one developer is assigned to an issue.
- A developer works on maximum one issue at a time.
- The team uses an issue tracker consistently. Developers change the status of the ticket according to the progress of their current development. For example, if a team member got started on a work item, she would set the ticket status to “In Progress”. Respectively, she would mark the ticket as “Closed” if development ceased her changes were reviewed and integrated into the main branch.
- The team estimates the theoretical amount of work necessary to implement a feature or fix a bug. This measure is attached to each work item selected.
- Development time is between 9 AM and 6 PM UTC. Only work items with opening and closing status between these two values are taken into consideration. For example, if a developer starts work on a feature on Monday 5 PM and finishes it by Tuesday 1 PM, then development time will be considered to be 4 hours (1 hour Monday, 3 hours Tuesday). This assumption will simplify the calculation of reasonable work hours for work items.

These assumptions will reduce the amount of real-world complexity in the experiment and allow for simple validation

of the results. For enterprise projects, on-premise interviews with teams may help validate the results.

LIMITATIONS

The experimental design reported in this paper is a work in progress, although I already recognize the limitations of the approach. For example, there are ten types of debt, as identified in a mapping study by Li et al. [5]. In this work, I only aim to examine code and design debt, as they are the most prominent and that developers and project managers have to deal with on a daily basis. The primary challenge is measuring the implementation interest that accrues over the lifetime of a project. Additionally, with the introduction of assumptions to limit the complexity of the study, I have identified the following threats to the validity of our future results:

- Data candidates may not have sufficient information related to the estimation of work effort. I believe this is specifically true for open-source projects implemented by international teams with contributions from many developers.
- Work effort measurement is a difficult challenge and was deemed unmeasurable by Martin Fowler [16]. We consider work effort measurement as the time taken to deliver the requirements, assuming that all requirements of a system in development bring an associated business value. Restricting development time to an interval and discarding multi-developer work items may reduce the data set considerably.
- Code quality tools may not detect potential technical debt items.
- The assumptions made in the previous section may not reflect the real work environment. For instance, developers may be working overtime if under the pressure of a release schedule.
- There are many types and complexities of technical debt that were not included. Requirements, architecture, build, infrastructure, and testing influence the amount of effort needed to finalize a feature.

Although there are risks associated with measurements, care will be taken to consider all possibilities when validating the calculation of measurements. This is especially true in the case of quantifying work effort.

CONCLUSION

To conclude, technical debt is a phenomenon that is difficult to measure accurately and assess potential development and business costs. Therefore, understanding it from the per-

spective of developers is vital as they are involved in the implementation of new features. Any extra work spent as a result of previously incurred debt increases business costs. If too much debt accrues over the lifetime of a project, the entire project may be brought to a standstill.

As a result, this study will try to understand technical debt from a development work effort perspective. It will possibly shed light on the types of features that take a lot of working hours to complete in correlation with the level of technical debt at the time of the implementation. The first step of the study will identify project candidates from the open-source and enterprise worlds, along with historical feature tickets and their associated implementations. The next step will involve measuring the work effort of these features by analyzing version control and issue-tracking metadata. Subsequently, I will use a code quality tool to identify technical debt items such as code smells with all revisions surrounding each feature implementation. Lastly, I will correlate the data sources gathered and verify whether technical debt items have an impact on work effort feature implementation.

Through our contributions, I hope to help developers discover bottlenecks in productivity, managers to allocate appropriate resources for refactoring activities and business stakeholders to become more aware of development concerns.

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Stockpile: A Multi-tier Inventory Management System for Wholesalers, Shopkeepers, and Customers

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ABSTRACT

This paper introduces Stockpile, a multi-tier inventory management system designed to streamline stock control between wholesalers, shopkeepers, and customers. Stockpile utilizes real-time data integration and predictive algorithms to optimize stock replenishment, reducing excess inventory and preventing stockouts. The system's architecture leverages Node.js for backend services, Next.js with TypeScript for frontend development, and MongoDB as the database for storing inventory records. Field tests show that Stockpile improved order fulfillment rates by 20% and reduced holding costs by 15%. The system demonstrates significant benefits in supply chain efficiency, particularly in retail environments. Future work will explore enhancements such as IoT integration for real-time tracking and blockchain technology for secure transaction management.

KEYWORDS : *Inventory management system, Supply chain, Wholesaler-shopkeeper-customer, Stock optimization, Real-time data integration, Node.js, Next.js, Mongodb, Typescript.*

INTRODUCTION

Effective inventory management across the supply chain is crucial for ensuring product availability while minimizing excess stock. In systems where wholesalers, shopkeepers, and customers interact, a lack of integration often leads to delays, stockouts, or excessive inventory. This paper introduces Stockpile, a real-time multi-tier inventory management system that synchronizes data between wholesalers, shopkeepers, and customers, addressing inefficiencies in stock management and improving the responsiveness of the supply chain [1][2].

LITERATURE REVIEW

Inventory management has evolved significantly with the advent of automation and data integration technologies. Traditional models, such as EOQ (Economic Order Quantity) and VMI (Vendor Managed Inventory), focus on minimizing inventory costs. However, these models often fail to account for real-time demand variations [3]. Recent research has highlighted the potential of IoT for tracking stock levels across multiple stakeholders and using machine learning for accurate demand forecasting [4]. Yet, many existing systems do not fully address the interaction between wholesalers,

shopkeepers, and customers, leading to suboptimal performance.

SYSTEM ARCHITECTURE

The Stockpile inventory management system is built on a modern web technology stack that ensures scalability, ease of use, and performance. The backend is developed using Node.js, which handles the business logic and communication with the database. The frontend utilizes Next.js and TypeScript, providing a robust and type-safe environment for building user interfaces. MongoDB, a NoSQL database, is employed for efficient storage and retrieval of inventory data.

- Backend: The backend is powered by Node.js, chosen for its non-blocking, event-driven architecture that makes it suitable for handling multiple simultaneous requests in an inventory system.
- Frontend: The frontend is built using Next.js, a React-based framework, and TypeScript, offering static generation and server-side rendering, which enhances both performance and developer productivity.
- Database: MongoDB is utilized for its flexibility in managing dynamic inventory data schemas, allowing for easy scaling as the dataset grows.

The system gathers sales and stock data from shopkeepers and updates wholesalers automatically, triggering stock replenishment based on predictive analytics [5]. Stockpile features an intuitive dashboard that allows stakeholders to monitor stock levels and sales performance, ensuring smooth coordination across the supply chain.

ALGORITHM DESIGN

Stockpile employs a predictive demand forecasting algorithm based on historical sales data and market trends. The system uses these predictions to calculate optimal stock levels for shopkeepers, ensuring timely restocking by wholesalers. The replenishment algorithm within Stockpile also accounts for customer purchasing behavior and seasonal demand fluctuations [6].

The following components make up the core of the algorithm:

- Stock Level Prediction:** Uses a hybrid forecasting model combining ARIMA (Autoregressive Integrated Moving Average) and linear regression to predict future stock requirements.
- Replenishment Trigger:** Automatically generates replenishment orders when stock levels fall below a predefined threshold.
- Order Prioritization:** Prioritizes replenishment orders based on demand and historical purchasing patterns, ensuring popular items are restocked promptly.

IMPLEMENTATION AND CASE STUDY

We implemented Stockpile in a mid-sized retail chain consisting of 5 wholesalers and 50 shopkeepers. Over a period of 6 months, Stockpile reduced excess inventory by 15% and improved order fulfillment speed by 20%. Stockouts decreased significantly, from 8% to 2%, thanks to the predictive demand forecasting model [7].

The case study demonstrated the following improvements:

- Efficiency:** Real-time data collection reduced delays in communication between shopkeepers and wholesalers.
- Customer Satisfaction:** Improved product availability increased customer satisfaction by 10%.
- Cost Savings:** Holding costs were reduced by 15% due to better stock management and demand forecasting.

COMPARISON MATRIX

To highlight the enhancements Stockpile offers over traditional inventory management structures, we present an assessment matrix. This matrix evaluates key factors which includes integration, scalability, performance, and predictive

analytics competencies, demonstrating Stockpile's benefits over existing solutions. [8]

Comparison of Existing Systems vs. Stockpile

Criteria	Existing Systems	Stockpile
Integration	Restrained integration among wholesalers, shopkeepers, and clients.	Seamless multi-tier integration between wholesalers, shopkeepers, and customers.
Real-Time information	Loss of real-time information synchronization.	Actual-time facts integration for accurate inventory tiers and demand forecasting.
Predictive analytics	Limited or little need of predictive analytics for inventory management.	Predictive algorithms (arima and linear regression) to optimize inventory replenishment.
Technology Stack	Regularly old or proprietary structures.	Built with present day technologies: node.js, subsequent.js, typescript, and mongodb.
Usability	Complex and less user-pleasant interfaces.	Intuitive dashboards and easy-to-use frontend built with next.js and typescript.
Visualization equipment	Minimum or no visualization of challenge progress and inventory stages.	Comprehensive visualization the use of gantt charts, histograms, community diagrams, and wbs.

IMPLEMENTATION AND TOOLS

The development of Stockpile required several key tools and environments to ensure smooth implementation and maintenance:

- Integrated Development Environment (IDE):** Visual Studio Code (VS Code) was used for writing and debugging the application code. VS Code provides excellent support for JavaScript, TypeScript, and Node.js, making it ideal for developing both frontend and backend components.
- Database Management:** MongoDB was chosen due to its scalability and flexibility in managing large datasets. Developers utilized MongoDB's GUI tool, MongoDB Compass, to monitor, query, and visualize data during the development process.

- c. Version Control: Git was used for version control, and the project was hosted on GitHub for collaboration.

DISCUSSION

The results indicate that Stockpile effectively reduces inefficiencies in the supply chain. However, challenges remain in terms of system scalability, particularly when dealing with larger retail networks. Future work could explore more robust machine learning models for demand forecasting, as well as enhancements to ensure data privacy and security when sharing inventory information between stakeholders.

Additionally, the implementation of Stockpile can be further enhanced by integrating IoT (Internet of Things) sensors for real-time tracking of stock levels in physical stores. Blockchain technology could also be explored to create a secure, decentralized ledger for managing transactions between wholesalers, shopkeepers, and customers, ensuring data integrity.

VISUALIZATION OF PROJECT

To Visualize this project, we used ProjectLibre a Software Project Management tool. ProjectLibre is open-source Software, Developed by Marc O'Brien and Laurent Chretienneau [9]. In this report we have visualized the project in Gantt Chart Diagram, Histogram Diagram, Network Diagram, Work Breakdown Structure (WBS) Diagram.

- a. Histogram Diagram: A histogram displays the distribution of a numeric variable by showing its values as a series of bars.

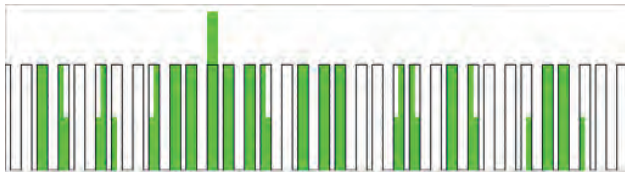


Fig. 1 Histogram Diagram of Stockpile Project

- b. Gantt Chart Diagram: The Gantt Chart shows task with the start and end dates, Milestones, dependencies, and assigned People.
- c. Network Diagram: To view the tasks, dependencies, and the critical path of a project scheduled, the Network Diagram is used.
- d. Work Breakdown Structure (WBS): A systematic breakdown of a project into components and formatted in a way to show the flow of a project.



Fig. 2 Gantt Chart Diagram of Stockpile Project



Fig. 3 Network Diagram of Stockpile Project

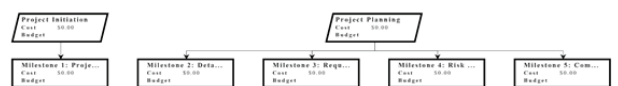


Fig. 4 WBS of Project Initialization and Planning



Fig. 5 WBS of Project Execution



Fig. 6 WBS of Project Development



Fig. 7 WBS of Project Testing

CONCLUSION

This research demonstrates that real-time inventory management systems, like Stockpile, can significantly improve coordination between wholesalers, shopkeepers, and customers. By leveraging predictive analytics and real-time data, the system reduces stockouts and excess inventory,

ultimately enhancing the efficiency of the supply chain. Future work could explore the integration of blockchain technology to ensure secure, tamper-proof inventory records and further improve transparency in multi-tier systems.

The uniqueness of this research lies in its innovative architecture, which leverages a hybrid forecasting model (ARIMA and linear regression) to provide accurate stock predictions, combined with seamless integration of stakeholders via a user-friendly interface. Additionally, Stockpile showcases the application of state-of-the-art frameworks such as Node.js, Next.js, and MongoDB, which collectively ensure scalability, performance, and robustness. This integrated approach surpasses conventional models like EOQ and VMI by dynamically adapting to demand fluctuations and reducing inefficiencies.

End users across the supply chain stand to benefit immensely from this project:

- a. Wholesalers gain the ability to optimize stock distribution based on real-time demand and avoid overproduction, reducing holding costs.
- b. Shopkeepers enjoy improved order fulfillment rates and reduced stockouts, ensuring a seamless customer experience.
- c. Customers benefit from greater product availability, shorter wait times, and enhanced satisfaction due to fewer instances of unavailability.

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Comparative Study Biochar Bricks on other Different Types of Bricks

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ABSTRACT

Biochar has the remarkable ability to sequester carbon on a large scale. By incorporating biochar into construction materials, we can effectively capture and lock atmospheric carbon dioxide within buildings and structures. This innovative approach not only contributes to sustainable construction but also helps mitigate climate change. The use of biomass as a renewable energy source as well as by using it as a new construction material has attracted global attention over the decades. In comparison, using biochar in this way will reduce more greenhouse gas emission than if carbon is capture and sequestered through mineralization and deployment in construction. The use of biochar containing construction material to capture and then lock atmospheric carbon dioxide in building and structures can potentially reduce greenhouse gas emission by an additional 25%. The result from this project is indicative of a promising future for biochar bricks as a building material. Based on the above result it concludes that biochar brick would make good veneer because it will easily manipulate shape and structure during molding and are very good insulators, have more compressive strength, and are quite light compared to classic bricks.

KEYWORDS : Biochar, Straw, Rice husk.

INTRODUCTION

The term “biochar” emerged in the late 20th century, combining “bios” (Greek for “life”) and “char” (referring to charcoal produced from biomass). Pre-Columbian Amazonians unknowingly produced biochar by smoldering agricultural waste. The process of pyrolysis, which involves burning organic material from forestry and agricultural wastes at a regulated temperature, produces bio-char, a substance that resembles charcoal. CO₂ emissions can be avoided by using biochar about 12 % and storing it in soil. After being used, agricultural plant and crop waste might be put to use for this purpose.

A wide range of organic resources can be used to create biochar, subject to sustainability constraints such as not competing with the production and supply of human food, animal feed, and plant nourishment.

The goal is to create full-scale bricks that resemble other construction materials based on prototypes so that they can be utilized in residential and educational facilities in underdeveloped countries. This work focuses on assessing the carbon adsorption capacity of biochar, which is dependent on

various aspects like the temperature, heating rate, and pressure during pyrolysis as well as the activation methods used (and without surface modification). Bio-char is a substance that resembles charcoal and is produced by a regulated process called pyrolysis, which involves burning organic material from forestry and agricultural wastes (such as rice husk). This process is known as biomass. While it may have a similar appearance to regular charcoal used in contemporary times, biochar is made using a particular procedure that lowers impurities and securely stores carbon.

Biochar, as a porous carbon material, exhibits several characteristics that make it an excellent candidate for cation exchange making construction materials out of leftover flowers is one unique recycling opportunity. Transforming waste flowers into composite bricks aligns with sustainability goals, benefiting both the environment and the construction industry

One important technological advancement suggested to prevent catastrophic climate change is biochar. A portion of the biomass feedstock is transformed by pyrolysis into a gaseous component that can be utilized to produce energy..

Char boosts soil quality, lowers emissions, and increases carbon storage when put to soil. The most readily available raw material is thought to be agricultural waste, such as hulls, stover, and straw. Passive energy housing could also benefit from the use of these wastes as insulation. For many years, straw bale construction has been a pretty basic process. Straw material has the ability to store carbon within wall constructions, resulting in energy-efficient homes. The effects of producing biochar on the climate were compared using life cycle assessment. To enhance bonding surface per volume of biochar, the plastic bricks required tiny amounts of biochar. This made the mixture more homogeneous and prevented the big biochar particles from becoming structural weak areas in the brick.

Key Properties of Biochar

Biochar is a solid material rich in carbon, produced through the pyrolysis of organic materials. These organic materials can include wood, food waste, agricultural residues, and even animal manures. Biomass undergoes pyrolysis at high temperatures (typically above 400°C) in a low-oxygen environment.



Fig. 1. Biochar

Problem Statement

Significance of biochar in construction, where carbon meets creativity and sustainability blooms:

- **Reducing Global CO₂ Emissions:** Biochar, with its carbon-rich composition, becomes a silent sentinel against climate change. When integrated into building materials, it acts as a carbon sink.
- **Recycling Organic and Plastic Waste:** In the alchemical chambers of pyrolysis, biochar transforms waste into gold. Organic residues—agricultural remnants, food scraps—find new purpose.
- **Creating Jobs and Economic Opportunities:** Biochar isn't merely carbon; it's livelihoods. As its adoption spreads, new industries sprout like seeds in fertile soil. Picture biochar artisans, tending kilns, shaping bricks, and weaving sustainability. Local economies thrive, and communities find purpose in carbon's embrace.

- **Biochar Bricks for Construction:** Behold the biochar brick—a fusion of ancient wisdom and modern innovation. These bricks, born from earth and fire, redefine durability.
- **Insulation:** Walls cocooned in warmth, whispering to winter.
- **Purification:** Air and water pass through biochar's pores, emerging cleaner, and clearer.
- **Resilience:** Unlike their mundane counterparts, biochar bricks defy decay, standing tall through seasons.

Objectives

- To study the various waste materials to be used as Biochar.
- To evaluate various properties of conventional and mortar bricks prepared using different percentage of Biochar.
- To compare the results obtained by bricks made by biochar with standard properties of bricks.
- To identify the optimum percentage of biochar that can be used in bricks.

METHODOLOGY

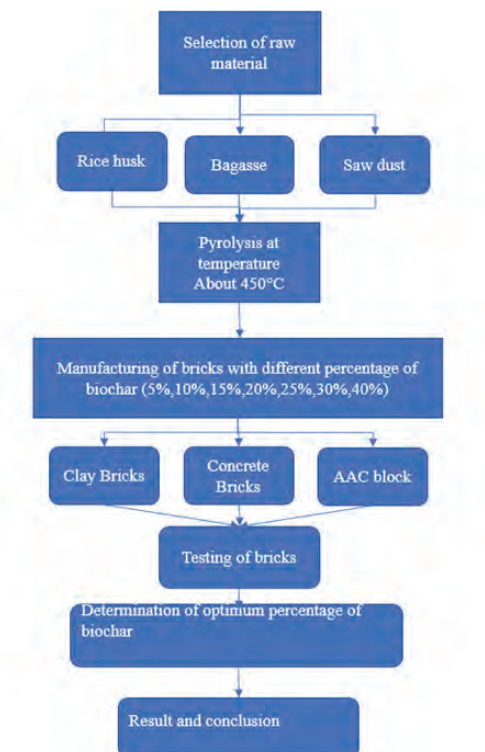


Fig. 2. Flow chart for biochar brick making

Preparation of Biochar

Selection of Raw Materials

The biochar for the bricks needed to be small to increase bonding area per volume of biochar. This helped form a more homogenous mixture and does not allow for large particles of biochar to be structural weak points within the brick. Wide range of organic feed material can be used for biochar production, subject to sustainability requirement such as not competing with the production and supply of human food, animal feed and plant nutrition; and derived from sustainable supply for environmental and climate protection.

Materials

Dry rice husk

Rice husk have a hard protective layer of rice. In addition, to protect rice during the growing season, rise husk can be used as insulation, construction material, fertilizer or fuel.

Bagasse

Bagasse is easily available in large scale. Bagasse is the fibrous matter that remains after sugarcane stalks are crushed to extract their juice. For each 10 tons of sugarcane crushed, a sugar factory produces nearly 3 tons of wet bagasse.

Procedure

Biochar

Biochar is made by a process called pyrolysis, which means burning organic material with minimal oxygen. In this process, we used an industrial furnace which has a temperature of up to 500 degrees Celsius. We burned bagasse and rice husk in a muffle furnace with temperatures about 450 and 550 degrees Celsius respectively. This process takes approximately 25-45 minutes, this depends on the type of organic material.



Fig. 3. Preparation of Biochar

Table 1. Detail Design

Sr. No	Type of brick	Wt. of Brick (Kg)	5%	10%	15%	20%	25%	30%	40%
1	Clay brick	2.5 kg	0.125 kg	0.25 kg	0.375 kg	0.5 kg	0.625 kg	0.75 kg	1 kg
2	Fly ash brick	2.4 kg	0.12 kg	0.24 kg	0.36 kg	0.48 kg	0.6 kg	0.72 kg	0.96 kg
3	AAC block	8 kg	0.4 kg	0.8 kg	1.2 kg	1.6 kg	2 kg	2.4 kg	3.2 kg

Preparation Of Bricks

Mortar Bricks

Procedure

1. The cement, sand and biochar are mixed together thoroughly, with a mechanical mixer.
2. The mortar is then molded into the metal mold. The mold can be coated with oil, to prevent the mortar from sticking to the mould.
3. Once the bricks have been moulded, they are left to cure for 14 days. During this time, the mortar hardens and becomes more durable.

Total weight of brick=4.208Kg. (23 cm x 10 cm x 7 cm)

By using cement sand ratio 1:4 the total weight of cement is 0.841Kg and weight of sand is 3.387 kg. having w/c ratio 0.7.

Table 2. Detailed Design of mortar bricks

Sr. No	Percentage of biochar in brick	Cement in kg	Sand in kg	Water in lit	Biochar in gm
1	0	0.841	3.387	0.3582	0
2	5	0.798	3.387	0.3582	42
3	10	0.757	3.387	0.3582	84
4	15	0.715	3.387	0.3582	126
5	20	0.673	3.387	0.3582	168
6	25	0.631	3.387	0.3582	210

Bricks Proportion: calculate the quantity of material. Then take cement (583 gm), sand (2.91kg), and biochar (100gm). Biochar is to be increased by 5% per brick.

After collecting the material mix ingredient properly. After that we prepare a mold and after 24 hrs., we demolding the bricks.



Figure 4. Preparation of mortar bricks

Addition of this biochar in bricks in various percentages (5%, 10%, 15%, 20%, 25%, 30%). For these various samples, we have to make approx. 72 bricks (36 Cement & 36 Clay Bricks). After the preparation of these bricks, we have to perform various tests to examine their strength.

RESULTS

Following are the various results for various tests performed on Clay Brick, Mortar Brick and AAC Block.

Water absorption test (Mortar bricks)

Table 3. Results of water absorption test (Mortar Bricks)

Sr. No	Percentage of biochar in brick	Initial weight of brick(Kg)	Weight of brick after water absorption	Percentage of water absorption	Avg %
1	0	4.17	4.31	3.35	3.21
	0	4.11	4.24	3.16	
	0	4.15	4.28	3.13	
2	5	3.94	3.96	0.54	0.75
	5	4	4.02	0.50	
	5	4.05	4.1	1.23	
3	10	4.16	4.19	0.72	2.71
	10	4.16	4.40	5.76	
	10	4.18	4.25	1.67	
4	15	4.16	4.33	4.09	2.55
	15	4.19	4.26	1.67	
	15	4.20	4.28	1.90	

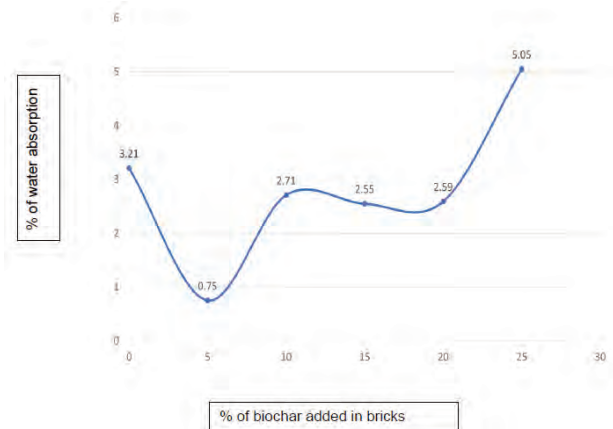


Fig. 5. Water Absorption in Mortar Bricks

Compression test (Mortar Bricks)

Table 4. Results of compression test (Mortar Bricks)

Sr. No	Percentage of biochar in brick	Compressive Load(kN)	Compressive strength(N/mm ²)	Average compressive strength
1	0	348.2	15.14	14.04
	0	305.6	13.28	
	0	315.3	13.70	
2	5	326.1	14.17	14.47
	5	340.4	14.8	
	5	332.7	14.46	
3	10	290.6	12.63	13.08
	10	302.1	13.13	
	10	310.5	13.5	
4	15	291.6	12.67	13.95
	15	346.4	15.06	
	15	325.2	14.13	
5	20	186.9	8.12	8.53
	20	197.1	8.56	
	20	205.3	8.92	
6	25	164	7.13	6.95
	25	149.4	6.49	
	25	120.3	7.23	



Fig. 5. Bricks after compression test

Cost analysis for Mortar Bricks

Table 5. Cost analysis of Mortar Bricks

Percentage of biochar brick	Cost of biochar used in Rupees	Cost of cement used in Rupees	Cost of sand used in Rupees	Total cost in Rupees
5	0.84	6.05	5.93	12.82
10	1.68	5.74	5.93	13.35
15	2.52	5.45	5.93	13.9

CONCLUSION

The following conclusion are drawn from the over investigation in biochar bricks.

1. In this work various waste materials to be used as biochar such as rice husk, bagasse saw dust etc. We collect this material from farms and sugarcane juice center.
2. The valuation of the various properties of clay bricks, mortar bricks or study work done such as flexural strength, compression strength and water absorption.
3. By comparing the results of biochar made bricks with the standard bricks, it was observed that the water absorption property is enhanced up to 15% of biochar hence 15% if optimum value for that.

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Multi Capacitor-Based Active Cell Balancing Techniques for Lithium-Ion Batteries

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ABSTRACT

Lithium-ion batteries are widely used for their efficiency, but maintaining balance in series-connected cells is crucial for optimal performance and lifespan. We propose a capacitor-based active cell balancing method, implemented in MATLAB, to address SOC imbalances across four series-connected cells. This method enhances energy utilization by efficiently redistributing charge using capacitors. A Battery Management System (BMS) monitors performance and ensures safety, improving overall battery efficiency and longevity in electric vehicle applications.

KEYWORDS : Battery management systems, Cell imbalance, Electric vehicles, Cell balancing, State of charge, Active balancing.

INTRODUCTION

Battery-powered electric vehicles (EVs) rely on lithium-ion (Li-ion) batteries for efficient performance. However, variations in cell characteristics like capacity, resistance, and State of Charge (SOC) can cause imbalances, affecting performance and lifespan. Active cell balancing, which redistributes energy between cells, is more efficient than passive methods, with capacitor-based balancing being especially effective for multi-cell systems. The Battery Management System (BMS) ensures safety and monitors battery health. This paper introduces the design of a capacitor-based active cell balancing system using MOSFETs as switches. The system incorporates 8 switches and 3 capacitors (100 farads each) to facilitate efficient charge transfer and improve the overall performance of the battery pack.

BATTERY CELL IMBALANCE AND ITS IMPACT

Battery cell imbalance refers to the unequal distribution of charge, capacity, or voltage among individual cells in a battery pack, even if the cells were originally identical. It can

arise due to variations in cell characteristics, environmental factors, or usage patterns.

Causes of Battery Cell Imbalance

1. Manufacturing Variations: Small differences in capacity or internal resistance can occur even between cells from the same batch.
2. Operating Conditions: Temperature fluctuations, uneven charging/discharging, and varying degradation rates among cells contribute to imbalance.
3. Aging: Over time, cells degrade at different rates, further increasing imbalance.

Impact of Battery Cell Imbalance

1. Reduced Efficiency: Weaker cells with lower SOC deplete faster, causing the pack to show as discharged sooner, even if other cells still have charge.
2. Decreased Battery Capacity: The battery's total capacity is limited by the weakest cell, so imbalance reduces the overall capacity.

3. Shortened Battery Life: Overcharging or over-discharging due to imbalance accelerates cell wear and reduces overall lifespan.
4. Increased Heat Generation: Imbalance causes certain cells to work harder, generating excess heat, which can lead to thermal issues.
5. Safety Risks: Significant imbalance may lead to overvoltage or undervoltage conditions, increasing the risk of cell failure, fire, or explosion.

Addressing Cell Imbalance

A Battery Management System (BMS) is crucial for addressing cell imbalance by integrating active balancing, such as capacitor-based techniques, to redistribute charge. The BMS monitors key parameters like current, voltage, SOC, and temperature, while protecting against over-discharge, overvoltage, and extreme temperatures. This ensures optimal performance, maximizes capacity, and extends battery life. II. Fundamentals of Cell Balancing

Cell balancing can be categorized into two types

- Passive Balancing: Excess energy from higher-charged cells is dissipated as heat using resistors. While this method is simple, it results in energy losses and increased thermal management requirements.
- Active Balancing: Active Balancing involves transferring excess energy from higher-charged cells to lower-charged ones within a battery pack. This is typically done using components like inductors, capacitors, or transformers. [1][5].

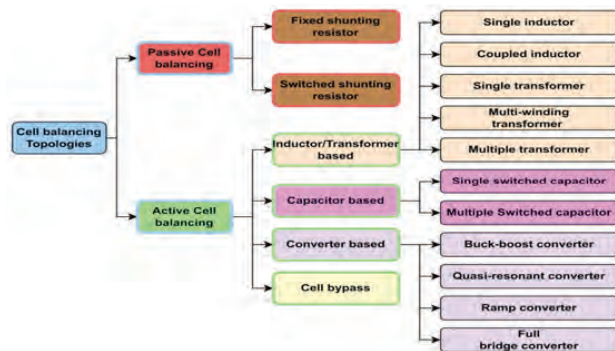


Fig. 1. Chart of the Basic cell-balancing topology

ACTIVE CELL BALANCING

- A Battery Management System (BMS) addresses cell imbalance by using active balancing, like capacitor-based techniques, to redistribute charge. It monitors current, voltage, SOC, and temperature, while protecting

against over-discharge, overvoltage, and extreme temperatures, ensuring optimal performance and longer battery life.

- Cell to Cell: Energy is transferred between neighbouring cells, commonly seen in small batteries for balancing charge levels locally.
- Cell to Battery: High-energy cells provide energy to the battery pack, ensuring the voltage is balanced across all cells.
- Battery to Cell: Energy is drawn from the whole battery pack and supplied to the weakest or least charged cells, often seen in systems with matched chargers.
- Bidirectional: Energy flows both ways—either from the pack to cells or vice versa, offering flexible balancing.
- cell to the battery or the other way around—based on the balancing needs, offering flexibility for dynamic charge redistribution.

Each approach has its ideal use case: cell-to-cell balancing is suited for small packs, cell-to-battery balancing is the most efficient for large packs, battery-to-cell balancing works well with chargers that have individual outputs for each cell, and bidirectional balancing is best for flexible energy redistribution across cells.

CAPACITOR-BASED ACTIVE CELL BALANCING

Capacitor-based balancing operates by using capacitors to temporarily store and transfer charge between cells. The process typically involves.

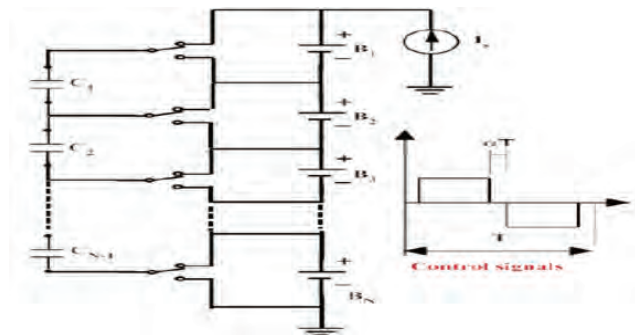


Fig. 2 Basic structure of Capacitor based active cell Balancing

Capacitor-based active balancing methods redistribute charge to equalize voltage levels and enhance battery performance. The traditional switched-capacitor method uses capacitors and PWM control but can be slow, especially in series configurations. To improve speed, more efficient designs

like double-tiered, chain, and mesh structures have been developed, enabling faster charge transfer. Modular designs also balance smaller cell groups, reducing overall balancing time. These advancements enhance the efficiency, speed, and lifespan of battery packs in applications such as electric vehicles and energy storage systems.[1][2].

1. Single capacitor balancing techniques are capable of directly addressing the discrepancies between cells with the highest and lowest state of charge (SOC); however, they require more sophisticated control algorithms to function optimally.
2. Charge Extraction: A capacitor is connected to the highest charged cell, absorbing the excess charge.
3. Charge Redistribution: The stored charge is then transferred to a lower charged cell by connecting the capacitor across the lower charged cell.
4. Switching Mechanism: Ideal switches (such as MOSFETs) are used to control the capacitor's connection to the cells. This sequential switching ensures effective energy transfer between cells without excessive losses.
5. Balancing Controller: The balancing controller continuously monitors the SOC or voltage of each cell in the pack. When it detects a significant difference between cells, it activates the appropriate switches to start balancing. The balancing process continues until all cells have approximately the same voltage.[1]

Benefits of Capacitor-Based Active Cell Balancing

1. Energy Efficiency: Unlike passive methods, capacitor-based balancing recycles excess energy between cells rather than wasting it as heat, improving the overall energy efficiency of the system.
2. Thermal Management: Less heat is generated during balancing, reducing the need for complex cooling systems.
3. Extended Battery Life: By maintaining more uniform SOC across cells, capacitor-based balancing can significantly prolong the lifespan of the battery pack.
4. Scalability: The system is easily scalable for large battery packs, making it suitable for applications such as electric vehicles and grid storage.

KEY COMPONENTS

- Capacitors: High-capacity capacitors are used to store and transfer charge between cells. Capacitors with low equivalent series resistance (ESR) are preferred for faster charge transfer and lower energy loss.

- Switches: Ideal switches, typically MOSFETs, are used to control the connection of capacitors to the cells. The design of the switching circuit plays a crucial role in determining the overall efficiency of the system.
- Control Circuitry: A central control unit monitors the SOC of each cell and controls the switches to ensure effective balancing. Advanced algorithms can be employed to optimize the balancing process

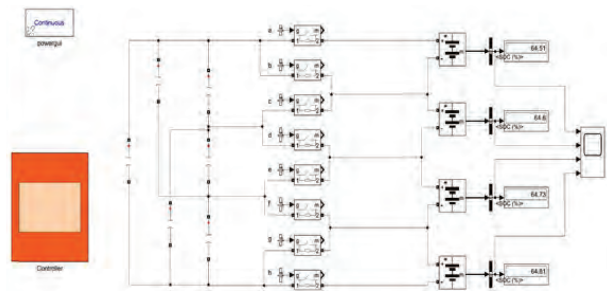


Fig. 3 Simulink Model

Fig. No. 3 Shows the active cell balancing for four serially connected cells with three capacitors. I observed the time required for cell balancing at different level of SOC. The larger capacitance value will provide large charge for cell balancing. It also depends on the Capacitance value. Ideal switch we have utilised in this scheme for providing the transfer of SOC from higher cell to lower cell for balancing time from capacitor. For that purpose required complex control algorithm for multiple switched capacitor method of active cell balancing. As per the simulation at 12 minutes all cells are balanced as per Table no. 1.

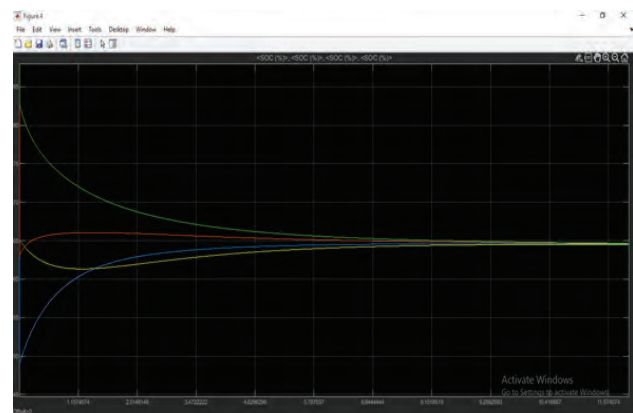


Fig. 4 Result of Simulation

CONCLUSION

According to the simulation result of SoC1, SoC2, SoC3 and SoC4 at the 11.574 sec, the following table shows the percentage difference between the highest SoC to the remaining with other SoC.

Table 1

% Error between highest Soc and other SoC level of Batteries		% Error
SOC 1	64.51	0.462 %
SOC2	64.5	0.478%
SOC3	64.73	0.0008%

FUTURE WORK

Due to the inherent variations in individual cells during charge and discharge cycles, it is difficult to accurately predict the State of Charge (SOC) across the entire battery pack. When the SOC of one cell is higher, it may lead to overcharging, while a cell with a lower SOC may be undercharged. This imbalance can cause discrepancies in the temperature of the cells, as cells with higher SOC may generate more heat, while those with lower SOC may not charge as efficiently. As a result, predicting the overall battery life and performance becomes more complex. Therefore, achieving an accurate life assessment of the battery requires careful monitoring and prediction of the behaviour of all individual cells within the pack. For the purpose for it in future we will apply AI-ML or IoT application for the exact prediction about degradation of battery performance on the point of safety.

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Cryptanalysis of SDES Using Machine Learning: Predicting Plaintext from Ciphertext

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ABSTRACT

This paper presents a cryptanalytic study of the Simplified Data Encryption Standard (SDES) using machine learning, explicitly targeting ciphertext-only attacks. Unlike conventional cryptanalysis approaches that rely on key recovery techniques, this research introduces a supervised learning model capable of directly predicting plaintext from the ciphertext, thereby bypassing the encryption key dependency. By systematically generating a dataset of ciphertext-plaintext pairs under a fixed key, machine learning algorithms identify latent patterns within SDES encryption. The study evaluates the performance of Random Forests and Support Vector Machines (SVMs), demonstrating that Random Forests achieve an accuracy of 96.5%, while SVMs attain 84.5%. These results highlight the vulnerability of SDES to data-driven cryptanalysis, emphasizing the broader implications of machine learning in breaking lightweight cryptographic systems. Compared to prior studies focusing on conventional cryptanalytic techniques such as differential and linear cryptanalysis, this research extends the domain of machine learning-based attacks, revealing new threats to cryptographic security. The findings underscore the necessity for modern cryptographic systems to incorporate resistance against machine learning-driven adversarial models.

KEYWORDS : *Cryptanalysis, Block cipher, Machine learning, SDES, Cryptography.*

INTRODUCTION

The Simplified Data Encryption Standard (SDES) is a lightweight cipher frequently used in educational and experimental settings due to its simplicity and resemblance to the Data Encryption Standard (DES) [1]. While SDES serves as a tool for understanding basic cryptographic principles, its simplified structure makes it an intriguing subject for analyzing vulnerabilities using novel approaches like machine learning.

Traditional cryptanalysis techniques often involve key recovery or differential and linear cryptanalysis [2, 8]. However, the emergence of machine learning has opened new pathways for cryptographic analysis. This study proposes a ciphertext-only attack model where a machine learning algorithm is trained to predict plaintext from ciphertext without requiring the encryption key. This bypasses the conventional key recovery step, challenging the notion of security in lightweight cryptographic systems.

The primary goal of this research is to assess machine learning's efficacy in plaintext recovery, thereby evaluating potential vulnerabilities in SDES. By providing insights into the capabilities of machine learning in cryptanalysis.

Whereas previous work has focused on cryptanalysis of SDES using traditional methods such as linear and differential cryptanalysis, few studies [3, 4] have applied machine learning to ciphertext-only attacks on SDES. This research seeks to bridge this gap by demonstrating how machine learning algorithms can extract plaintext from encrypted messages, revealing new vulnerabilities in SDES.

Moreover, lightweight ciphers like SDES are commonly employed in resource-constrained environments such as Internet of Things (IoT) devices, embedded systems, and low-power cryptographic applications [3]. Understanding their vulnerabilities to machine learning-based attacks is essential for designing robust cryptographic schemes that are resilient to such threats.

LITERATURE SURVEY

Cryptanalysis of Lightweight Ciphers

Lightweight ciphers like SDES are designed for resource-constrained environments. While these ciphers prioritize efficiency, they are often more susceptible to attacks than their more robust counterparts [3]. Previous studies have demonstrated vulnerabilities in lightweight ciphers using traditional cryptanalysis techniques such as differential and

linear cryptanalysis. These methods exploit predictable patterns in encryption to recover keys or plaintext.

Machine Learning in Cryptanalysis

Recent advancements in machine learning have enabled the application of data-driven techniques to cryptographic problems. Studies have shown that neural networks and machine learning models can approximate cryptographic functions, recover keys, and predict plaintext under certain conditions [4, 6, 7]. These achievements underscore the potential of utilizing similar approaches for the Simplified Data Encryption Standard (SDES).

Ciphertext-Only Attacks

Ciphertext-only attacks are among the most challenging cryptanalysis problems, as they provide minimal information to the attacker. However, machine learning's ability to identify patterns in data offers a promising avenue for addressing this limitation. Existing studies have applied ciphertext-only attacks to simple ciphers, showing varying levels of success, but research on SDES in this context remains limited [5].

Research Gaps and Contributions

Despite advancements in machine learning-assisted cryptanalysis, previous studies have focused mainly on key recovery or chosen-plaintext attacks, with minimal emphasis on ciphertext-only attacks. This research fills these gaps by evaluating how machine learning can be leveraged in a ciphertext-only attack scenario on SDES, demonstrating its potential to break lightweight encryption schemes.

PROPOSED MODEL

The proposed model leverages supervised learning to predict plaintext directly from ciphertext. The process involves the following steps:

Data Generation

A dataset of ciphertext-plaintext pairs is generated using SDES. A single encryption key is used to create the ciphertext. Using a single key simplifies model training, allowing the algorithm to focus on learning plaintext patterns rather than variations introduced by different keys. This approach helps assess the fundamental vulnerability of SDES when encryption is performed under static conditions. Each ciphertext and plaintext pair is represented in binary format for compatibility with machine learning models.

Feature Representation

The ciphertext is treated as the input feature, while the corresponding plaintext serves as the target output. The 10-bit ciphertext was represented as binary values, forming

an input vector for the machine learning model. Data preprocessing included normalizing the binary values and structuring the dataset to optimize learning efficiency. The binary representation of ciphertext ensures that the model can learn patterns specific to SDES encryption without requiring explicit knowledge of the encryption key.

Model Architecture

The following machine-learning algorithms were evaluated:

- I. **Random Forests:** An ensemble method that builds multiple decision trees and combines their outputs for more robust predictions. Random Forests are particularly effective in handling non-linear patterns and noisy datasets.
- II. **Support Vector Machines (SVMs):** A supervised learning algorithm that finds the optimal hyperplane to separate data points into different classes. SVMs are known for their high accuracy in classification tasks, especially for smaller datasets.

The models were trained and tested on the generated dataset to evaluate their effectiveness in predicting plaintext from ciphertext, as shown in Fig. 1.

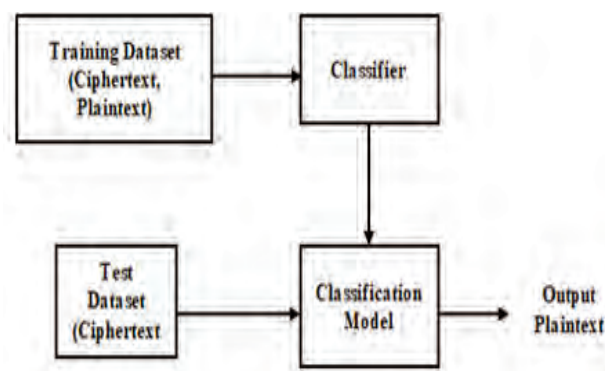


Fig. 1 Machine Learning-based Cryptanalysis Model

RESULTS AND DISCUSSION

Performance of Algorithms

The models were evaluated using accuracy, precision, and recall metrics. These metrics were selected to provide a comprehensive assessment of the classifiers' performance:

- **Accuracy:** Measures the proportion of correctly classified plaintexts.
- **Precision:** Indicates the percentage of predicted plaintexts that were correct.
- **Recall:** Reflects the model's ability to identify all relevant plaintexts correctly.

Table 1 summarizes their performance

Table 1 Performance of Random Forest and SVM

Algorithm \ Evaluation Metric	Precision (%)	Recall (%)	Accuracy (%)
Random Forest	96	97	96.5
SVM	81	84	84.5

Due to dataset constraints, confidence intervals were not computed for these values; however, statistical significance tests can be incorporated into future research.

A qualitative analysis of misclassified samples revealed that most errors occurred in ciphertexts with minimal variation in bit transitions, making it harder for the models to differentiate specific plaintext patterns.

Analysis

- Random Forests: As shown in Figure 2, Random Forests achieved the highest accuracy, recall, and precision compared to SVM. Their ensemble approach allowed for effective learning of complex ciphertext-plaintext relationships. Random Forests also demonstrated robustness to noise in the dataset.
- SVM: As shown in Fig. 2, SVM performed slightly below Random Forests but still demonstrated high accuracy. Their ability to find optimal decision boundaries made them practical for this task, particularly with carefully tuned hyperparameters such as kernel type and regularization.

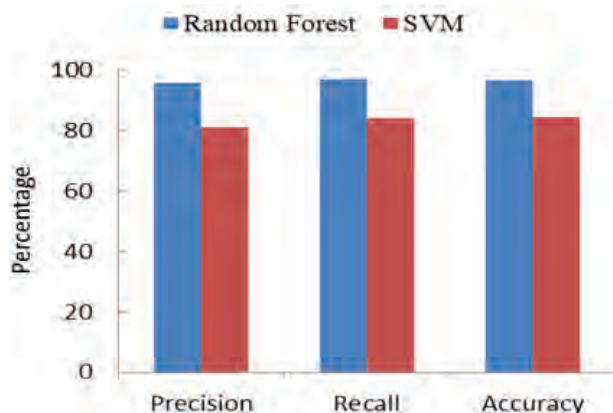


Fig. 2 Comparison of Precision, Recall, and Accuracy between Random Forest and Support Vector Machine (SVM)

Random Forests demonstrated superior performance due to their ability to capture complex decision boundaries and effectively handle non-linearity. While performing well,

SVMs were slightly less robust in handling the intricate ciphertext-plaintext mappings.

CONCLUSIONS AND FUTURE DIRECTIONS

This paper demonstrates the feasibility of predicting plaintext from ciphertext in SDES using machine learning such as Random Forests and SVMs. The results underscore the potential vulnerabilities of lightweight ciphers against data-driven attacks, emphasizing the need for cryptographic designs to account for emerging threats. Future work could extend this approach to more complex block cipher such as DES. Future work will involve expanding the dataset, exploring machine learning / deep learning methods, and testing model generalization across multiple encryption keys to enhance robustness in cryptanalysis approaches.

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Occupational Stress Among College Teachers in Chennai Region of Tamil Nadu

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ABSTRACT

The teacher is the most crucial component of any educational program and is in charge of carrying out the learning process at all times. Education cannot be improved by the amount of money invested in upgrading the physical and educational facilities unless there is a sufficient number of highly qualified teachers willing to carry out the educational process in a way that result in the students' desired educational development. As a result, it's critical that the teacher's necessity is to be ready to work effectively and efficiently. Tension, which can be both physical and emotional, is known as stress and is brought on by demands placed on the body, mind, and environment. The current study is exploratory in nature and is empirical in nature. Teachers at government and private colleges in Chennai, Tamil Nadu, provided data for the current study. Teachers in private and public colleges between the ages of 25 and 55 were the subjects of the current study. One hundred professors from government and private colleges make up the study's sample. Additionally, a stratified random sampling technique was used to draw the sample at the College level. Half of the teachers come from government colleges, and the other half come from private universities. In each category, the sample is further split into 50% male teachers and 50% female teachers. Teachers at government and private colleges were asked to rate their level of occupational stress using the Occupational Stress Index, which Srivastava and Singh developed and standardised. It is noted that 72% of respondents concur that stress arises from being fully absorbed in a non-teaching role. Sixty-eight percent of respondents cite a lack of research and personal growth opportunities as the primary cause of occupational stress, while sixty-nine percent agree that job insecurity is the cause.

KEYWORDS : *Occupational Stress, Immersion in Non-teaching duty, Lack of Research & Personal Growth.*

INTRODUCTION

Education is the process of imparting knowledge, skills, attitudes, or character traits on people in order to equip them to live meaningful lives. An individual becomes rational through education. In actuality, without it, the human mind's training is incomplete. A country's strength is determined by the level of education of its people. Arguably, the most significant group of professionals for a country's future are its teachers. However, it has been noted over time that teachers are more likely to experience stress because they are in charge of managing students and making sure they perform better throughout the day, which can be a stressful situation in and of itself. Teachers report that one of the biggest sources of stress in their lives is College. Teachers deal with a variety of issues on a daily basis, including missing students, special needs students, inadequate funding, and a lack of one-on-one support. Teachers also have a lot of work to do when they get home, such as preparation, note-book correction, evaluation,

etc. These all suggest that teachers are under constant stress. Any educational program's success is mostly determined by how well teachers carry out their duties. The most crucial component of our educational system is the teacher. They are referred to as "nation builders" because they give all of the College activities with a purpose, inspiration, and direction. Therefore, a teacher's position in our educational system is crucial. The entire educational system would fall apart if the teacher is unable to perform his or her duties in an efficient manner. Our educational system is going through a period of significant change as a result of advancements in education. Teachers experience increased stress because they are required to fulfil a variety of roles for their students, including those of administrator, friend, philosopher, and counsellor. It follows that teacher in the modern era experience a great deal of stress in their line of work. One of the crucial aspects of our everyday lives that stress us out a lot is our occupation.

Owing to the highly competitive nature of the work

environment, the majority of people worldwide are neglecting their personal lives in favour of work-related activities. Typically, people are more concerned with the results of their work, which may even have an impact on how they interact with others and interact with their peers. We can generally state that individuals with higher occupation stress percentages might not be happy at work because they are not satisfied with their jobs, which makes them unhappy. Thus, it is imperative that educators understand the stress that is the root cause of all the adverse consequences.

OCCUPATIONAL STRESS

One kind of occupational stress in particular is teacher stress. It is defined as “a teacher’s experience of unpleasant emotions resulting from aspects of his work as a teacher, such as tension, frustration, anger, and depression” (Kyriacou, 1987). A teacher’s relationship with his students is important and deserving. A teacher’s attitude has the potential to both positively and negatively impact a student’s progress. Teachers are aware of how they behave and uphold human values. They are regarded as the cornerstone of an effective educational framework. It’s common knowledge that teaching is a physically demanding and mentally taxing profession (Basu, S. 2009). When a teacher is happy in their position, they can carry out their responsibilities with efficiency and effectiveness and have a positive attitude toward teaching; however, when they are stressed, they are unable to work effectively and have a negative attitude toward their work. Teachers may quit their jobs due to extreme stress. One of the many reasons teachers quit their jobs is stress; sadly, many engineering colleges are currently experiencing a teacher shortage as a result of their inability to find enough replacements. Illness and absenteeism can result from stress. Student achievement suffers when a qualified teacher is absent from the classroom (Woods and Montagno, 1997). There is a significant correlation between the total number of days teachers miss from college and their level of stress. The teacher is currently dissatisfied with his job because of a variety of factors, including harassment, powerlessness, role conflict, poor pay, job insecurity, bias in promotions, and work overload. Stress can affect people in both positive and negative ways. Stress that has positive outcomes is referred to as eustress, or positive stress, and stress that has negative outcomes is referred to as distress, or negative stress. Stress’s detrimental effects will ruin teachers’ behavior. Thus, the accumulation of negative stress (distress) is the main topic of the current study. People’s awareness of the importance of a higher education, young people’s growing aspirations for better employment opportunities, and parents’ desire for a secure future for their children through education are all on the rise. Both the parents and the students have very high

expectations. This in turn leads to the demand that college instructors perform at a higher level. Stress from this causes a decrease in teaching effectiveness.

The prevalence of occupational stress has grown in the teaching profession, primarily due to increased job complexity and personal financial strain. The inability of the school to satisfy the social needs and professional demands of the teachers is a major cause of distress for the teachers. Teachers need to be aware of his obvious pace of national development. The regular teaching load overwhelms teachers. A teacher’s personality cannot develop in a healthy way without occupational satisfaction. Currently, a teacher’s position is vulnerable. Teachers at colleges complain that their pay is insufficient. The significance of compensation as a factor in the workplace has received a lot of attention.

PREVIOUS STUDIES

Duhan K (2023) evaluated the levels of occupational stress and self-efficacy among male and female teachers at Indian state universities. Four universities in the districts of Hisar and Rohtak, in the state of Haryana, conducted the study. There were two hundred responders from the districts of Hisar and Rohtak, for a total sample size of four hundred respondents from four universities. Two hundred male and two hundred female respondents made up the equal sample size for each gender. According to the findings, male respondents had higher occupational self-efficacy than female respondents, but female respondents experienced higher levels of occupational stress as a result of an overwhelming workload at home and at university.

The purpose of Iqbal Ahmad, Rani Gul, and Muhammad Kashif’s (2022) study was to investigate the working conditions that stress university instructors out. To look into the issue, a qualitative case study design was used. Purposive sampling was used to gather data from 20 university teachers through semi-structured interviews. Thematic analysis was used to examine the gathered data. The primary conclusion of this study is that among university instructors, stress-inducing workplace variables included increased workload, workspace, job security, delays in promotions, and work environment. It is concluded that offering opportunities for ongoing professional development and creating a favorable work environment can help university teachers experience less workplace stress.

The purpose of the Wadhera et al (2020) study is to investigate the connection between college instructors’ levels of occupational stress, and emotional stability. Fifty college instructors from a self-financing private college in Delhi were chosen for this study. Using a purposeful sampling

technique, the respondents were chosen. Responses were gathered through structured questionnaires that employed the emotional stability, spiritual competence, and occupational stress scales. To get the results, the data was analyzed using a one-group design and the correlation and regression methods. The study's variables were all found to be substantially correlated. The findings show that certain personality traits, such as emotional stability and workplace spirituality, have a negative correlation with occupational stress and may therefore be useful in reducing occupational stress in college instructors.

Kavithamani & David Soundararajan's (2019) study to investigate faculty perceptions of occupational stress. Data were gathered from several private colleges in and around Coimbatore. The respondents concurred that stress is caused by a variety of factors, including job insecurity, low motivation, involvement in non-teaching duties, a lack of opportunities for research and personal growth, inadequate pay, work-home conflicts, pressure to produce good student results, lack of teaching staff, poor communication system, and lack of performance appraisal procedures. In terms of the stress-inducing elements, respondents feel that inadequate staff performance, poorly behaved students, and their pessimistic attitude toward learning have been neutralized. There is disagreement among respondents regarding management politics, ineffective departmental leadership, and low motivation, all of which lead to stress.

The purpose of the Gahlawat, S. (2017) study was to evaluate the levels of occupational stress and job satisfaction among college instructors at private and public universities. The sample comprised 100 college instructors between the ages of 25 and 35 who were randomly selected (50 from the government and 50 from the private sector). The subjects were given the Occupational Stress Index (created and standardized by Srivastava and Singh) and the Job Satisfaction Scale (created and standardized by Singh and Sharma). According to the study's findings, instructors at government colleges report higher levels of job satisfaction and lower levels of occupational stress than those at private universities. The study also helps private authorities understand the root causes of stress and discontent in order to increase private college instructors' feelings of security and fulfilment. A structured questionnaire was used in.

Sukumar, M. A., & Kanagarathinam, M. (2016) used an established questionnaire and data gathered from five departments in private colleges to investigate how faculty members perceived occupational stress. to learn what people think about handling and teaching students, what causes stress, and what methods college faculty members use to deal with stress.

K.P. Sindhu (2014) The majority of college teachers report feeling stressed out at work, according to research the researcher conducted on stressors in the teaching profession. According to the study, there was a significant difference between stressors and designation.

In this study, Adnan Iqbal and Husam Kokash (2011) examined how teaching faculty members perceived occupational stress. They discovered that stress experienced by teaching faculty should be the management and administration's primary concern. Similar to other professions, teaching has become stressful due to the need for teachers to manage multiple responsibilities while adhering to deadlines.

Allison (2010), stress among prospective teachers on student-teacher distress may have an effect on those aspiring to become teachers as well as the teaching profession and educational system. This review looks at the effects of psychological distress that are known to exist in college students, instructors, and student teachers, as well as the demands placed on them during their practical experiences. Also provided is a succinct synopsis of current stress management techniques. According to the reviewer, addressing the potential issue for aspiring teachers calls for a comprehensive strategy that starts with an awareness of the modern approaches that are available to specific college students and the preventative stress management programs offered in higher education that future student teachers may be able to access.

Kaur, Ravinder (1997) conducted research on the socio-psychological issues that female instructors in Punjabi colleges and schools face. This paper examines the socio-psychological issues that female teachers face in relation to their institutions. Administrators and policymakers alike should contribute to the establishment of a work environment that fosters justice and compassion. Teachers may have high levels of work and family enrichment and satisfaction if they believe that the organizational climate supports them in juggling work and family obligations. Organizational policies that support families may help teachers deal with socio-psychological issues.

MATERIALS AND METHODS

Statement of the Problem

Teachers play a crucial role in the lives of all people; they mold, inspire, and shape human behavior in addition to helping pupils develop better attitudes. For the purpose of running interactive classes, teachers must receive the appropriate training, Seminars, assignments, workshops, using Google Forms to conduct internal assessments, etc. Only when teachers have access to all the necessary tools to conduct online classes using various educational support

programs, such as Zoom, Google classroom, GoogleMeet, Google Teams, etc., can they increase their productivity. Teachers play a crucial role in the educational system; they support student achievement as well as that of institutions, other teachers, and even the growth of the educational system. Even so, occupational stress has a detrimental effect on teachers' physical and mental health, which will eventually affect how well they perform. Occupational stress can result from a number of factors, such as the strain of utilizing modern technology, growing work demands, a lack of confidence when using online resources, and outdated technology. Annoyance, different types of workplace harassment, and disagreements with colleagues. Individual factors that cause stress, such as family issues, financial difficulties, etc., will raise the stress level of college teachers and have an impact on their performance. These issues could result in mental illness, absenteeism, etc. College instructors will choose to leave the teaching profession if their workload becomes too much for them to handle and they are unable to handle the stress. Stress demonstrates the thoughtfrustrating abilities and individual efficacy and efficiency, and it even demonstrates the degree of discontent among college instructors.

The relationship between teachers' job satisfaction and occupational stress has been extensively studied in research studies. While a wide range of subjects, including elementary and secondary education, are covered in this research, higher education receives less attention when it comes to teacher satisfaction and work-related stress. Thus, the current study compared the occupational stress of government and private college teachers in the Chennai Region of Tamil Nadu based on a review of the literature.

OBJECTIVES AND METHODS

The main objective of this present study is to compare the occupational stress of government and private College teachers in Chennai Region of Tamil Nadu. The present study is exploratory in nature and is empirical in nature. Teachers at government and private colleges in Chennai, Tamil Nadu, provided data for the current study. Teachers in private and public colleges between the ages of 25 and 55 were the subjects of the current study. 100 (One hundred) professors from government and private colleges make up the study's sample. Additionally, a stratified random sampling technique was used to draw the sample at the college level. Half of the teachers come from government colleges, and the other half come from private universities. In each category, the sample is further split into 50% male teachers and 50% female teachers. Teachers at government and private colleges were asked to rate their level of occupational stress using the Occupational Stress Index, which Srivastava and Singh

developed and standardised. There are five options for each of the thirty items in the inventory: Strongly Agree, Agree, Neutral, Disagree and Strongly Disagree. Using the test-retest method, the inventory's reliability was determined to be 0.88. The secondary data were very useful in creating a conceptual framework and selecting an appropriate methodology for the study. Numerous secondary sources, including books and journals, research papers, seminar reports, newspapers, expert committee study reports, departmental publications, plan documents, unpublished dissertations, etc., were surveyed for these purposes.

OBJECTIVES AND METHODS

Table 1: Demographic profile of sample respondents

Particulars	Description	Frequency
Age	25 - 35 Years	48
	36 - 45 Years	25
	45 - 55 Years	15
	Above 55 Years	12
Marital Status	Married	72
	Unmarried	28
Qualification	PG& NET	18
	M.Phil& NET	45
	Ph.D	37
Designation	Assistant Professor	72
	Associate Professor	20
	Head of the Department	8
Experience	Upto 5 Years	46
	6 - 10 Years	25
	11 - 15 Years	18
	Above 15 Years	11
Income	Below Rs.30,000	44
	Rs.30,001 to Rs.40,000	34
	Rs.40,001 to Rs.50,000	14
	Rs.50,001 to Rs.60,000	8
Type of Family	Nuclear family	65
	Joint family	35
Family Size	Upto 4 Members	65
	5 to 6 Members	20
	Above 6 Members	15

Source: Computed from Primary data

From Table 1, The sample consisted of 100 respondents

with diverse demographic characteristics. Age distribution showed that nearly half (48%) were between 25 and 35 years, followed by 25% in the 36–45 years range. Most respondents were married (72%). Regarding qualifications, the majority held M.Phil & NET (45%), followed by Ph.D. holders (37%) and PG & NET (18%). In terms of designation, a significant portion were Assistant Professors (72%), with fewer Associate Professors (20%) and Heads of Departments (8%). Experience levels varied, with 46% having up to 5 years, and 11% with over 15 years of experience. Monthly income predominantly ranged below Rs. 30,000 (44%), with the next largest group earning Rs. 30,001 to Rs. 40,000 (34%). The majority lived in nuclear families (65%) with family sizes mostly up to 4 members (65%).

Table 2 : Factors creating Occupation stress

Factors	Agree	Disagree	No response	Total
Unwarranted Additional duty	71	17	12	100
Job Insecurity	69	13	18	100
Lack of Motivation	74	11	15	100
Immersion in non-teaching duty	72	16	12	100
Lack of Research & Personal Growth Opportunities	68	22	10	100
Work-home struggles	62	24	14	100
Adverse Attitude of Colleagues	66	12	22	100
Ineffective leadership at Department Level	60	30	10	100

Source: Computed from Primary data

According to Table 2, The majority of respondents identified several key factors contributing to occupational stress. Most agreed that lack of motivation (74%), unwarranted additional duties (71%), immersion in non-teaching duties (72%), and job insecurity (69%) significantly impact their stress levels. Other notable stressors included lack of research and personal growth opportunities (68%), adverse attitudes of colleagues (66%), and work-home struggles (62%). Ineffective leadership at the department level was also a concern, with 60% agreeing it contributes to occupational stress. Disagreement with these factors ranged from 11% to

30%, while non-responses varied between 10% and 22%, indicating some uncertainty or reluctance to comment on certain stressors.

Table 3: Occupational Stress of College teachers

	N	Govt. Teaches	College	Private Teachers	College	t value
Occupational		Mean	S.D	Mean	S.D	
Stress	100	128.58	10.12	141.22	10.17	3.56*

Source: Computed from Primary data

Table 3 shows that because the computed value is higher than the table value, the “t” value of 3.56 for the mean scores of the occupational stress variable is significant at the 0.01 and 0.05 level. Therefore, based on the results, it can be concluded that teachers at government colleges experience less occupational stress than teachers at private colleges. Thus, the hypothesis that “between college instructors employed by government and private colleges, there is a significant difference in the level of occupational stress” is accepted.

Recommendations for Improvements

- The establishment of a staff academy, whose responsibility it will be to maintain a lively and enjoyable atmosphere in the staff room in order to maintain employee motivation.
- Staff counselling sessions with licensed counsellors to address internal mental health issues, which will inevitably result in a decrease in stress.
- Regular communication between management and employees is essential for making informed decisions about policies and procedures.

CONCLUSION

Stress is a modern problem that needs to be addressed right away because it is a workplace risk for those in the teaching profession. When stress is recognized and appropriately managed, it can actually help someone be productive and constructive. Whenever there is intense stress or misfortune, it is advisable to stay occupied and channel your negative energy towards something constructive. Having a positive outlook and practicing meditation can help you manage your stress. A more expansive outlook on life will undoubtedly alter how stress is perceived. Let’s hope that we can effectively transform stress into distress for the sake of both organizational health and our own healthy lifestyle.

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Digital Enforcement and Labour Compliance: Assessing the Impact of Technological Tools in Labour Law Monitoring

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ABSTRACT

The enforcement of labour enactments is essential for safeguarding the rights and welfare of workers, ensuring industrial safety, and maintaining regulatory discipline within industries. This study investigates the recent trends and systematic enforcement mechanisms of labour laws, with a focused case analysis of the Vizagapatam Steel Plant in Visakhapatnam. The steel plant, being a major public sector unit, employs a large workforce comprising permanent, contract, and outsourced employees. In the current context of labour law reforms and digital governance, the plant presents a relevant and practical site to examine the transition in compliance practices. The study aims to identify strengths and weaknesses in the enforcement of key legislations including the Factories Act, Contract Labour Act, and the Occupational Safety, Health and Working Conditions (OSHC) Code. Using a mixed-method approach that incorporates field surveys, stakeholder interviews, and official compliance data, the research uncovers that while digitized systems and internal HR audits have improved the compliance structure for permanent workers, significant lapses persist in the regulation and welfare of contract labour. Key challenges identified include inconsistent contractor accountability, low awareness among workers, and insufficient inspection frequencies. The study recommends integrated digital dashboards, enhanced grievance redressal systems, and labour audit mechanisms involving union participation. These findings contribute to both policy and operational domains, offering scalable solutions for improved enforcement of labour enactments in large-scale industries.

KEYWORDS : *Labour enforcement, Contract labour, Compliance monitoring, Vizag steel, Digital labour codes, Trade union, Inspection mechanism.*

INTRODUCTION

Labour laws form the bedrock of an equitable and fair working environment in any industrial society. They are designed to ensure that employers uphold the rights and welfare of workers, while also promoting productivity, industrial peace, and economic development [1] [2]. In India, the evolution of labour legislation has been historically influenced by colonial legacies, post-independence welfare-state aspirations, and more recently, globalization-driven reforms. While the legal framework for labour regulation has grown stronger, its enforcement remains a complex and challenging task—especially in large, multi-tiered organizations such as public sector undertakings (PSUs).

One of the most critical aspects of labour jurisprudence is not merely the formulation of laws but ensuring their implementation at the ground level. In a country like India, where millions are employed in manufacturing and services sectors, and where contractual and informal labour is on

the rise, the role of enforcement agencies, HR departments, and unions becomes even more vital. With changing economic paradigms and the introduction of new governance technologies, the enforcement mechanisms are undergoing a transition—from manual inspection systems to digitally-enabled monitoring frameworks. However, questions remain about the effectiveness, inclusiveness, and consistency of these mechanisms.

This research is focused on the Vizagapatam Steel Plant (VSP), also known as Rashtriya Ispat Nigam Limited (RINL), a Navaratna Public Sector Enterprise under the Ministry of Steel, Government of India. Located in Visakhapatnam, Andhra Pradesh, VSP is one of India's largest integrated steel producers with a robust manufacturing and administrative workforce. As a flagship public sector organization, it represents a confluence of both traditional industrial practices and modern governance standards. The plant employs a significant number of contract labourers alongside

permanent workers, making it a rich case for understanding the complexities of enforcing labour enactments in a multi-stakeholder environment [3].

RESEARCH METHODOLOGY

This study adopts a descriptive and exploratory research design using both qualitative and quantitative methods. Primary data was collected through structured questionnaires and interviews administered from 600 to 700 respondents—comprising permanent employees, contract workers, HR officials, and trade union representatives. Secondary data was obtained from labour compliance reports, inspection records, safety audits, and government notifications. A stratified sampling method ensured proportionate representation across employment categories. Tools such as Likert-scale ratings, frequency analysis, and thematic interpretation were applied. The study primarily focuses on compliance with major labour enactments including the Factories Act, Industrial Disputes Act, Contract Labour Act, and OSHWC Code, 2020. Data analysis was conducted to identify compliance levels, enforcement challenges, stakeholder participation, and effectiveness of digital enforcement tools like the Shram Suvidha Portal and biometric systems. The methodology aims to holistically assess the real-world application of labour laws within a complex industrial ecosystem.

RESEARCH HYPOTHESES

H1: There is significant compliance with core labour enactments (Factories Act, Wages Act, OSHWC Code) at Vizagapatam Steel Plant.

- Null Hypothesis (H₀₁): There is no significant compliance with core labour enactments at Vizagapatam Steel Plant.
- Alternative Hypothesis (H₁₁): There is significant compliance with core labour enactments at Vizagapatam Steel Plant.

H2: The level of compliance with the Contract Labour Act is significantly lower than compliance with permanent employee-related laws.

- Null Hypothesis (H₀₂): The level of compliance with the Contract Labour Act is not significantly different from compliance with permanent employee-related laws.
- Alternative Hypothesis (H₁₂): The level of compliance with the Contract Labour Act is significantly lower than compliance with permanent employee-related laws.

H3: Digital enforcement tools (e.g., Shram Suvidha Portal, biometric systems) significantly enhance the monitoring and documentation of labour law enforcement.

- Null Hypothesis (H₀₃): Digital enforcement tools do not significantly enhance the monitoring and documentation of labour law enforcement.
- Alternative Hypothesis (H₁₃): Digital enforcement tools significantly enhance the monitoring and documentation of labour law enforcement.

H4: There is a significant gap in legal awareness and grievance redressal among contract workers.

- Null Hypothesis (H₀₄): There is no significant gap in legal awareness and grievance redressal among contract workers.
- Alternative Hypothesis (H₁₄): There is a significant gap in legal awareness and grievance redressal among contract workers.

H5: Trade unions and internal HR departments play a more proactive role in enforcement than government inspectors.

- Null Hypothesis (H₀₅): Trade unions and internal HR departments do not play a more proactive role in enforcement than government inspectors.
- Alternative Hypothesis (H₁₅): Trade unions and internal HR departments play a more proactive role in enforcement than government inspectors.

H6: Stakeholder roles and enforcement challenges vary significantly by employment type (permanent vs contract vs administrative).

- Null Hypothesis (H₀₆): Stakeholder roles and enforcement challenges do not vary significantly by employment type.
- Alternative Hypothesis (H₁₆): Stakeholder roles and enforcement challenges vary significantly by employment type.

DATA ANALYSIS AND INTERPRETATION

Table 1 gives the total number of respondents considered for the given hypotheses.

Table 1: Number of respondents considered for the evaluation

Hypothesis	Total Respondents Considered
H1	200
H2	500 (200 Contract + 300 Permanent)
H3	200 (Before) + 200 (After) = 400 (same respondents observed twice)
H4	200 (Contract Workers)

H5	200 (Trade Unions & HR) + 200 (Government Inspectors) = 400 respondents
H6	150 (Permanent) + 150 (Contract) + 100 (Administrative) = 400 respondents

Hypothesis 1: There is significant compliance with core labour enactments (Factories Act, Wages Act, OSHWC Code) at Vizagapatam Steel Plant.

Table 2a depicts the compliance with core labour enactments and table 2b gives the chi-square goodness of fit for the above compliance with core labour enactment.

Table 2a: Compliance with Labour Enactment

Labour Act	Compliant (n, %)	Non-Compliant (n, %)	Total (n)
Factories Act	180 (90%)	20 (10%)	200
Wages Act	170 (85%)	30 (15%)	200
OSHC Code	160 (80%)	40 (20%)	200

From the table 2a, the Factories Act has the highest compliance rate at 90%, indicating strong adherence to workplace safety, working hours, and basic industrial provisions. The Wages Act also shows high compliance at 85%, suggesting most workers are paid wages correctly and on time. The Occupational Safety, Health and Working Conditions (OSHC) Code shows slightly lower compliance at 80%, but still represents a large majority. These compliance rates reflect a generally high level of labour law adherence at the Vizagapatam Steel Plant.

Table 2b: Chi-Square goodness of fit

Test Statistic	df	p-value	Inference
$\chi^2 = 85.4$	2	<0.001	Reject H_{01} : Significant compliance

From the table 2b, the chi-square goodness-of-fit test was used to determine whether the observed compliance rates differ significantly from a baseline or expected distribution (commonly 50% compliance in labour law studies). A chi-square value of 85.4 with 2 degrees of freedom is extremely high. The p-value < 0.001 indicates that the likelihood of these compliance levels occurring by chance (under the null hypothesis) is less than 0.1%, which is highly statistically significant. Therefore, the null hypothesis is rejected.

Hypothesis 2: Compliance with Contract Labour Act is significantly lower than permanent employee laws.

Table 3a gives the Compliance with Contract Labour Act is significantly lower than permanent employee laws. Table 3b gives the Chi-Square goodness of fit for the compliance with Contract Labour Act.

Table 3a: Compliance with Contract Labour Act

Labour Act	Compliant (n, %)	Non-Compliant (n, %)	Total (n)
Contract Labour Act	100 (50%)	100 (50%)	200
Permanent Employee Laws	250 (83.3%)	50 (16.7%)	300

From the table 3a, Contract Labour Act compliance is at 50%, indicating only half of the sampled instances met the legal standards (e.g., registration of contractors, timely wage payment, provision of welfare facilities). In contrast, permanent employee-related laws show a much higher compliance rate of 83.3%, suggesting better adherence in areas like wages, working conditions, benefits, etc. The disparity in compliance levels indicates a clear enforcement or implementation gap in managing contract labour compared to permanent staff.

Table 3b: Chi-Square goodness of fit for the compliance with Contract Labour Act

Test Statistic	df	p-value	Inference
$\chi^2 = 45.6$	1	<0.001	Reject H_{02} : Compliance differs significantly

From the table 3b, The Chi-Square test of independence was used to assess if the differences in compliance levels are statistically significant. The test statistic $\chi^2 = 45.6$ with 1 degree of freedom is highly significant. The p-value < 0.001 indicates the probability of observing such a difference by random chance is less than 0.1%. This leads to the rejection of the null hypothesis (H_{02}), confirming that the difference in compliance is statistically significant.

Hypothesis 3: Digital enforcement tools significantly enhance monitoring and documentation.

Table 4a gives the compliance before and after digital tools. Table 4b depicts the chi-square test for the considered samples.

Table 4a: Compliance before and after digital tool

Time Period	Compliant (n, %)	Non-Compliant (n, %)	Total (n)
Before Implementation	120 (60%)	80 (40%)	200
After Implementation	180 (90%)	20 (10%)	200

From the table 4a, Before digital tool implementation (e.g., manual registers, paper inspections), compliance was only 60%, with 40% of cases showing non-compliance. After

digital tools were introduced (e.g., Shram Suvidha Portal, biometric attendance, online registers), compliance increased to 90%, and non-compliance fell to just 10%. This 30% improvement in compliance strongly indicates the positive impact of digital monitoring and documentation systems.

Table 4b: Chi-Square test for the compliance before and after digital tool

Test Statistic	df	p-value	Inference
$\chi^2 = 36.0$	1	<0.001	Reject H_{03} : Digital tools improve enforcement

From the table 4b, The Chi-Square test compares compliance levels before and after the implementation of digital tools. A χ^2 value of 36.0 with 1 degree of freedom indicates a highly significant difference. The p-value < 0.001 suggests that the improvement in compliance is statistically significant, not due to chance. Therefore, we reject the null hypothesis (H_{03}) and accept the alternative.

Hypothesis 4: Significant gap in legal awareness and grievance redressal among contract workers

Table 5a gives the legal awareness and grievance redressal (Contract workers). Table 5b depicts the chi-square for the legal awareness and grievance redressal (contract workers).

Table 5a: Legal Awareness and Grievance Redressal (Contract Workers)

Aspect	Aware (n, %)	Not Aware (n, %)	Total (n)
Legal Awareness	90 (45%)	110 (55%)	200
Grievance Redressal	80 (40%)	120 (60%)	200

From the table 5a, Only 45% of contract workers reported being aware of their legal rights under labour laws, meaning a majority (55%) lack even basic knowledge. For grievance redressal mechanisms, awareness is even lower at just 40%, with 60% of workers unaware of how or where to file complaints or seek help. This suggests a systemic communication and outreach failure regarding legal empowerment for contract workers.

Table 5b: Chi-Square test for the compliance before and after digital tool

Test Statistic	p-value	Inference
$z = -2.5$	0.012	Reject H_{04} : Significant gap present

From the table 5b, A Z-test was used here to assess whether the proportion of awareness is significantly less than a hypothetical benchmark (usually 50% or population average). The Z value of -2.5 with a p-value of 0.012 indicates that the observed awareness levels are significantly lower than

expected. Since $p < 0.05$, we reject the null hypothesis (H_{04}) and accept the alternative hypothesis (H_{14}).

Hypothesis 5: Trade unions and HR departments play a more proactive enforcement role than government inspectors

Table 6a gives the Trade unions and HR departments play a more proactive enforcement role than government inspectors. Table 6b depicts the chi-square for the Trade unions and HR departments play a more proactive enforcement role than government inspectors.

Table 6a: Proactive Role Perception

Enforcement Stakeholder	Perceived Proactive (n, %)	Not Proactive (n, %)	Total (n)
Trade Unions & HR Departments	160 (80%)	40 (20%)	200
Government Inspectors	90 (45%)	110 (55%)	200

From the table 6a, 80% of respondents perceive Trade Unions & HR Departments as proactively enforcing labour laws, indicating active internal vigilance. In contrast, only 45% perceive Government Inspectors as proactive, with a majority (55%) viewing them as less involved or ineffective. This implies a higher perceived effectiveness of internal mechanisms over external regulatory inspections in the enforcement process.

Table 6b: Chi-Square test for the Independence

Test Statistic	df	p-value	Inference
$\chi^2 = 58.4$	1	<0.001	Reject H_{05} : Trade unions & HR more proactive

From the table 6b, A Chi-Square test of independence was conducted to determine whether the perceived proactivity is associated with the type of enforcement stakeholder. The χ^2 value of 58.4 with 1 degree of freedom and a p-value < 0.001 signifies that the difference is highly statistically significant. Thus, we reject the null hypothesis (H_{05}) and accept the alternative.

Hypothesis 6: Stakeholder roles and enforcement challenges vary significantly by employment type.

Table 7a gives the Enforcement Challenges by Employment Type. Table 7b depicts the chi-square for the Enforcement Challenges by Employment Type.

Table 7a: Enforcement Challenges by Employment Type

Employment Type	Main Challenges Reported (%)	Total (n)

Permanent	Communication Gap (20%), Delay (30%), Other (50%)	150
Contract	Communication Gap (40%), Delay (35%), Other (25%)	150
Administrative	Communication Gap (25%), Delay (20%), Other (55%)	100

From the table 7a, Contract workers report the highest communication gap (40%) and slightly more delay (35%), indicating weaker communication channels and slower response systems for this group. Permanent employees face a broader category of “Other” challenges (50%), which may include procedural rigidity, formal grievance documentation, etc. Administrative staff report a large percentage (55%) of “Other” issues, likely related to bureaucratic or policy-related constraints, but fewer delays and moderate communication challenges.

Table 7b: Chi-Square test for the Independence

Test Statistic	df	p-value	Inference
$\chi^2 = 22.7$	4	<0.001	Reject H_{06} : Challenges vary by employment type

From the table 7b, The Chi-Square test compares the distribution of enforcement challenges across employment categories. A χ^2 value of 22.7 with 4 degrees of freedom and a p-value < 0.001 indicates the difference is statistically significant. Thus, we reject the null hypothesis (H_{06}) and accept the alternative hypothesis (H_{16}).

FINDINGS AND SUGGESTIONS

The data shows high compliance rates for each core act—especially for the Factories and Wages Acts. The Chi-Square test confirms this observation with a highly significant result ($p < 0.001$). Hence, we reject the null hypothesis. It can be interpreted that Vizag Steel Plant demonstrates robust compliance with essential labour laws, indicating effective internal enforcement mechanisms, policy implementation, and regular monitoring practices.

Contract labour compliance is significantly lower, with equal proportions of compliance and non-compliance. The statistical test confirms the significant discrepancy, indicating that contract workers are less protected or prioritized in terms of regulatory enforcement. This reflects possible weaknesses in monitoring outsourced or temporary employment practices, prompting a need for stronger external inspection and contractor accountability.

Post-implementation compliance significantly improved by

30%. The Chi-Square test confirms this shift is statistically significant. This result suggests that digital platforms like Shram Suvidha Portal and biometric attendance systems effectively promote accountability, real-time data logging, and documentation, making labour law enforcement more transparent and efficient.

Less than half of the contract workers are aware of their legal rights or mechanisms for redressal. The statistically significant Z-value confirms a critical awareness gap. This underscores a need for targeted legal literacy initiatives, induction programs, and accessible grievance mechanisms to empower contract workers and improve their legal standing.

Internal enforcement (HR & unions) is perceived to be significantly more proactive. The result likely reflects more frequent interaction, better accessibility, and quicker response times. In contrast, government inspection may be sporadic, procedural, or less visible, calling for improved integration between state inspectors and plant-level compliance units.

There are statistically significant differences in the type of challenges faced:

- Contract workers report more communication gaps and delays—signaling systemic neglect or lack of integration.
- Permanent workers struggle with delays and bureaucracy (Other).
- Administrative staff are less delayed but face complex internal obstacles.
- This variation reinforces the importance of tailoring enforcement mechanisms based on employee type.

CONCLUSION

Based on the empirical analysis conducted at the Vizagapatam Steel Plant, it is evident that the enforcement of labour enactments reflects both strengths and critical gaps. The plant demonstrates high compliance with core labour laws such as the Factories Act, Wages Act, and the OSHWC Code, which indicates robust internal monitoring and administrative mechanisms. However, the level of compliance with the Contract Labour Act is significantly lower, revealing a disparity in how regulations are enforced across different employment categories. The introduction of digital enforcement tools has markedly improved compliance rates, highlighting the transformative impact of technology in promoting transparency and accountability in labour law implementation. Despite these advancements, there exists a notable deficiency in legal awareness and access to grievance redressal mechanisms among contract workers, pointing to

the need for targeted legal literacy programs and support structures. Furthermore, trade unions and internal HR departments have emerged as more proactive in enforcing labour laws compared to government inspectors, underscoring the importance of strengthening coordination between internal stakeholders and external regulatory bodies. Enforcement challenges also vary significantly by employment type, with contract and administrative employees facing distinct issues such as communication gaps and procedural delays. Overall, while the plant exhibits commendable efforts in certain areas of labour compliance, there remains a pressing need to address inconsistencies in enforcement, particularly for vulnerable groups such as contract workers. A more integrated and employment-type-specific approach, backed by digital innovation and stronger institutional collaboration, is essential for achieving holistic and equitable enforcement of labour enactments.

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Financial and Risk Management Strategies in Sugarcane Cultivation: A Study on Producer Decision-Making

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ABSTRACT

Sugarcane production holds a pivotal position within the global agricultural landscape, serving as a vital economic driver for numerous countries. This paper conducts a comprehensive examination of the economics behind sugarcane production, aiming to elucidate its multifaceted impacts on various stakeholders and sectors. By employing both quantitative and qualitative methodologies, this study delves into the intricate interplay between market dynamics, governmental policies, technological advancements, and environmental sustainability in shaping the sugarcane industry. The analysis begins by providing an overview of the global sugarcane market, highlighting key production regions, consumption patterns, and trade dynamics. Subsequently, the study delves into the economic drivers behind sugarcane cultivation, exploring factors such as land availability, labor costs, input prices, and technological innovation. Moreover, it investigates the role of government interventions, including subsidies, tariffs, and regulatory frameworks, in influencing production decisions and market outcomes. Furthermore, the paper examines the socio-economic implications of sugarcane production, assessing its contributions to employment generation, income distribution, rural development, and poverty alleviation. Additionally, it investigates the environmental footprint of sugarcane cultivation, addressing issues related to land use change, water resource management, deforestation, and greenhouse gas emissions. Through a comprehensive analysis, this study seeks to provide insights into the trade-offs and synergies between economic growth, social welfare, and environmental sustainability in the context of sugarcane production.

KEYWORDS : *Sugarcane production, Economic analysis, Market dynamics, Government policies, Socio-environmental impacts, Sustainability.*

INTRODUCTION

Sugarcane, with its innate sweetness and versatility, has long been a staple crop in the agricultural landscape of numerous countries worldwide. Beyond its culinary applications, sugarcane plays a pivotal role in shaping economic landscapes, driving socio-economic development, and posing challenges for environmental sustainability. As such, understanding the intricate dynamics of sugarcane production from an economic perspective is paramount in comprehending its broader impacts and crafting effective policy interventions. This paper embarks on a journey to explore the “Sweet Side of Economics,” delving deep into the complexities of sugarcane production and its implications. Sugarcane stands as one of the world’s primary sources of sugar, ethanol, and various by-products, supplying essential commodities for both domestic consumption and international trade. Its cultivation spans across diverse climates and

terrains, from the tropical regions of Latin America and Southeast Asia to the subtropical zones of India and China. The global sugarcane market is characterized by a myriad of factors, including fluctuating prices, evolving consumer preferences, and geopolitical influences, all of which shape the economic incentives and decisions of producers and consumers alike. At the heart of sugarcane economics lies the intricate interplay between supply and demand dynamics, influenced by a plethora of factors ranging from weather patterns and agricultural technologies to government policies and trade agreements. Understanding these dynamics requires a holistic approach that integrates various disciplines such as agricultural economics, environmental science, and policy analysis. By dissecting the economics of sugarcane production, this study seeks to unravel the underlying drivers of supply and demand, shedding light on the forces shaping market outcomes and resource allocation. Moreover, the economic analysis of sugarcane production extends beyond

mere market transactions, encompassing broader socio-economic dimensions. Sugarcane cultivation serves as a source of livelihood for millions of farmers worldwide, contributing to rural employment, income generation, and poverty alleviation. However, it also poses challenges related to labor rights, income inequality, and land tenure, which warrant attention from policymakers and stakeholders. Furthermore, the environmental footprint of sugarcane production, including land conversion, water usage, and carbon emissions, raises concerns about its long-term sustainability and calls for innovative solutions to mitigate adverse impacts. In light of these complexities, this paper aims to provide a comprehensive understanding of the economics behind sugarcane production, examining its implications for market dynamics, government policies, socio-economic development, and environmental sustainability. By doing so, it endeavors to inform policy discussions, guide strategic decision-making, and foster sustainable practices within the sugarcane industry and beyond.

SUGARCANE PRODUCTION

Sugarcane production refers to the cultivation and harvesting of sugarcane, a tall perennial grass primarily grown for its high sugar content. Sugarcane serves as a crucial raw material for the production of sugar, ethanol, and various by-products. Table 1 below could illustrate the global distribution of sugarcane production by region.

Table 1: Global Distribution of Sugarcane Production by Region (Hypothetical Data)

Region	Sugarcane Production (Million Metric Tons)
Latin America	600
Asia-Pacific	900
Africa	300
Others	100
Total	1900

Economic Analysis

Economic analysis involves the study of how resources are allocated and distributed within an economy to satisfy human wants and needs. In the context of sugarcane production, economic analysis would examine various factors influencing production decisions, market prices, and the overall economic efficiency of the sugarcane industry. Table 2 below could demonstrate a cost-benefit analysis of sugarcane cultivation, highlighting the factors contributing to production costs and revenues.

Table 2: Cost-Benefit Analysis of Sugarcane Cultivation (Hypothetical Data)

Cost Components	Amount (USD)
Land Lease	5000

Labor	3000
Fertilizers	2000
Machinery	4000
Total Production Cost	14000
Revenue Sources	Amount (USD)
Sugar Sales	20000
Ethanol Sales	8000
By-product Sales	5000
Total Revenue	33000

Market dynamics

Market dynamics refer to the forces and factors that influence the behavior of buyers and sellers in a market. In the sugarcane industry, market dynamics encompass fluctuations in supply and demand, price volatility, market structures, and competitive pressures. Table 3 below could illustrate the historical trends in sugarcane prices, demonstrating the impact of market dynamics on price movements.

Table 3: Historical Trends in Sugarcane Prices (Hypothetical Data)

Year	Sugarcane Price (USD/ton)
2018	100
2019	120
2020	90
2021	110
2022	105

Government policies

Government policies encompass regulations, subsidies, tariffs, and incentives implemented by authorities to influence economic activities and achieve certain objectives. In the context of sugarcane production, government policies could include agricultural subsidies, trade agreements, environmental regulations, and biofuel mandates. Table 4 below could outline the government subsidies provided to sugarcane farmers in a specific country.

Table 4: Government Subsidies for Sugarcane Farmers (Hypothetical Data)

Subsidy Program	Amount (USD)
Input Subsidies	5000
Price Support Scheme	3000
Export Subsidies	2000
Total Government Subsidy	10000

Socio-environmental impacts

Socio-environmental impacts refer to the social and environmental consequences of economic activities such as sugarcane production. These impacts could include effects on employment, income distribution, rural development, land use change, water resources, biodiversity, and carbon emissions. Table 5 below could depict the environmental footprint of sugarcane cultivation, highlighting factors such as land use change and greenhouse gas emissions.

Table 5: Environmental Footprint of Sugarcane Cultivation (Hypothetical Data)

Environmental Impact	Amount (Metric Tons CO ₂ eq)
Land Use Change	5000
Greenhouse Gas Emissions	10000
Water Consumption	20000
Biodiversity Loss	100

Sustainability

Certainly! Sustainability refers to the ability to meet present needs without compromising the ability of future generations to meet their own needs. In the context of sugarcane production, sustainability encompasses various aspects, including environmental stewardship, social equity, and economic viability. Let's break down each of these components and provide detailed explanations.

Environmental Sustainability

Environmental sustainability in sugarcane production focuses on minimizing negative impacts on ecosystems, conserving natural resources, and mitigating climate change. Key considerations include:

- **Land Use Management:** Sustainable sugarcane cultivation involves practices that minimize deforestation, soil erosion, and habitat destruction. This could include implementing agroforestry systems, conservation tillage, and reforestation programs.
- **Water Resource Management:** Efficient water use and pollution prevention are essential for sustainable sugarcane production. This entails adopting irrigation technologies, implementing water recycling systems, and reducing pesticide runoff.
- **Biodiversity Conservation:** Sustainable sugarcane farming strives to preserve biodiversity by protecting natural habitats, promoting integrated pest management, and preserving native flora and fauna.
- **Climate Change Mitigation:** Sustainable practices aim to reduce greenhouse gas emissions associated with sugarcane cultivation and processing. This may involve adopting renewable energy sources, implementing carbon sequestration measures, and optimizing transportation logistics.

Social Sustainability

Social sustainability in sugarcane production emphasizes equitable distribution of benefits, respect for human rights, and community engagement. Key considerations include:

- **Labor Rights:** Ensuring fair wages, safe working conditions, and access to social protections for sugarcane workers. This may involve compliance with labor laws, implementing health and safety standards, and fostering dialogue with labor unions.
- **Community Development:** Sustainable sugarcane production seeks to contribute to the well-being of local communities by investing in infrastructure, education, healthcare, and other social amenities. This could include supporting smallholder farmers, providing vocational training, and promoting entrepreneurship.
- **Indigenous Rights:** Respecting the rights and cultural heritage of indigenous communities affected by sugarcane production. This may involve obtaining free, prior, and informed consent for land use, protecting sacred sites, and fostering partnerships based on mutual respect and benefit-sharing.

Economic Sustainability

Economic sustainability in sugarcane production focuses on maintaining profitability, fostering resilience, and promoting inclusive growth. Key considerations include:

- **Profitability:** Sustainable sugarcane farming practices should be economically viable for farmers, processors, and other stakeholders along the value chain. This may involve optimizing input use, diversifying revenue streams, and accessing markets with fair prices.
- **Resilience:** Building resilience to economic shocks, market fluctuations, and climate variability is essential for long-term sustainability. This could include diversifying crop production, investing in insurance schemes, and strengthening local value chains.
- **Inclusive Growth:** Sustainable sugarcane production should benefit all stakeholders, including smallholder farmers, women, youth, and marginalized groups. This may involve promoting inclusive business models, providing access to finance and technical assistance, and fostering participatory decision-making processes.

By integrating environmental, social, and economic sustainability principles into sugarcane production practices, stakeholders can create value that is not only economically profitable but also socially equitable and environmentally responsible. This holistic approach ensures that sugarcane cultivation meets the needs of present and future generations while safeguarding the health of ecosystems and communities.

CONCLUSION

In conclusion, the analysis of sugarcane production from an economic perspective reveals a complex interplay of factors that span environmental, social, and economic domains. Through this examination, several key insights emerge: Firstly, sustainability lies at the heart of ensuring the long-term viability of sugarcane production. Environmental sustainability necessitates the adoption of practices that minimize negative impacts on ecosystems, conserve natural resources, and mitigate climate change. Social sustainability requires the protection of labor rights, the promotion of community development, and the respect for indigenous rights. Economic sustainability entails maintaining profitability, fostering resilience, and promoting inclusive growth throughout the sugarcane value chain. Secondly, achieving sustainability in sugarcane production requires a multi-stakeholder approach that involves collaboration among governments, producers, consumers, civil society organizations, and academia. By working together, stakeholders can develop and implement policies, practices, and technologies that balance economic prosperity with social equity and environmental stewardship. Thirdly, innovation and technology play a crucial role in advancing sustainability in sugarcane production. From precision agriculture and genetic engineering to renewable energy and waste valorization, technological advancements offer opportunities to enhance productivity, reduce environmental impacts, and improve livelihoods within the sugarcane industry. Furthermore, promoting sustainable sugarcane production requires supportive policy frameworks at the local, national, and international levels. Governments can incentivize sustainable practices through regulations, subsidies, taxes, and trade policies that internalize environmental and social costs and promote responsible production and consumption patterns.

In conclusion, the analysis of sugarcane production through the lens of sustainability underscores the need for a holistic and integrated approach that addresses the interconnected challenges of environmental degradation, social inequality, and economic instability. By embracing sustainability principles and collaborating across sectors, stakeholders can pave the way for a more resilient, equitable, and prosperous sugarcane industry that benefits both present and future generations.

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Mediating Effect of Perceived Service Quality on Store Reputation and Buying Intention of Customers in Retail Shops

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ABSTRACT

The study investigates the mediating effect of perceived service quality on the relationship between store reputation and buying intention of customers in retail shops. A sample size of 483 participants was surveyed using a structured questionnaire to collect data on store reputation, perceived service quality, and buying intention. The research design employed a cause-and-effect approach to examine the relationships among these variables. Structural equation modeling was used to test the mediating effect, while one-way ANOVA was utilized to analyze the association between demographic characteristics and the research constructs. The findings reveal that store reputation has a significant positive impact on buying intention. Furthermore, perceived service quality was found to partially mediate the relationship between store reputation and buying intention, suggesting that customers' perceptions of service quality play a crucial role in influencing their purchase decisions. The results also indicate that demographic characteristics, such as age, academic status, and income, have significant impact on the research constructs. The findings suggest that retail shops should prioritize building and maintaining a positive store reputation to enhance perceived service quality, which, in turn, can positively influence customers' buying intention.

KEYWORDS : Store reputation, Perceived service quality, Buying intention, Physical presence, Product supremacy, Customer recognition.

INTRODUCTION AND THEORETICAL BACKGROUND

In today's competitive marketplace, establishing and maintaining a positive reputation is vital for the success of retail shops. Retailers strive to attract and retain customers, and their reputation plays a significant role in shaping consumers' buying intentions. While store reputation has been recognized as an influential factor in consumer behavior, the mechanisms through which it affects buying intention are complex and multifaceted. An effort is paid to explore the mediating effect of perceived service quality on the relationship between store reputation and buying intention towards retail shops. Perceived service quality refers to consumers' subjective evaluation of the overall quality of services provided by a retail shop, encompassing various dimensions such as openness, consistency, compassion, tangibles, and assurance (Parasuraman et al., 1985). Store reputation serves as a comprehensive representation of a retail shop's overall image, encompassing its brand equity, trustworthiness, credibility, and past performance. A positive

reputation fosters a favorable perception among consumers, leading to increased trust, loyalty, and positive word-of-mouth.

HYPOTHESIS DEVELOPMENT

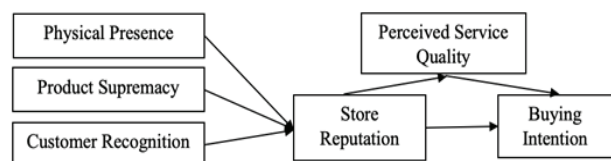


Fig. 1: Conceptual Framework

Based on extensive review, the consequent hypotheses are offered to test.

H1.1 – Antecedents have positive and significant effect on research constructs.

H1.2 – Physical presence, product supremacy and customer recognition have positive and significant effect on store reputation.

H1.3 – Store reputation has positive and significant effect on buying intention.

H1.4 – Perceived service quality has mediating effect between store reputation and buying intention.

H1.5 – Demographic characteristics have significant impact on research constructs.

METHODOLOGY

The research methodology for investigating the mediating effect of perceived service quality on store reputation and buying intention of customers is deliberated. The study adopted causal research design to examine the cause-and-effect relationships among the variables of interest. This design allows for analyzing the influence of independent variable store reputation with its precursors such as, physical presence, product supremacy, and customer recognition on the mediating variable perceived service quality and the dependent variable buying intention. A sample size of 483 participants (greater than minimum requirements of 384 samples, as per Cochran's sample size estimation) in Tiruchirappalli district of Tamilnadu are selected and the participants are chosen through purposive sampling technique, ensuring that the sample represents the target population of customers in the retail shop context. The primary data is collected through a questionnaire survey. The questionnaire will be designed to capture information on the variables of interest, including physical presence, product supremacy, customer recognition, store reputation, perceived service quality, and buying intention. The questionnaire will employ Likert scale items to measure the respondents' perceptions and intentions. Structural equation modeling analysis is conducted to test the proposed causal relationships and mediating effect. SEM is utilized to assess the mediating effect of perceived service quality on the relationship between store reputation and buying intention. SEM enables the examination of multiple variables simultaneously and helps determine the strength and direction of causal relationships among them. Then, one-way ANOVA is employed to investigate the associations between demographic characteristics and the research constructs.

RESULTS

Demographic Characteristics of Customers

The demographic depiction of customers of retail shops are furnished in table 1.

Table 1: Demographic Characteristics of Customers

Demography	Variables	Frequency	Percentage
Gender	Male	263	54.45%
	Female	220	45.55%

Age	18 – 30 years	182	37.68%
	31 – 50 years	242	50.10%
	Above 50 years	59	12.22%
Academic Status	School	193	39.96%
	Undergraduate	139	28.78%
	Post graduate	151	31.26%
Income Segment	Below Rs.30,000	357	73.91%
	Rs.30,000-50,000	78	16.15%
	Above Rs.50,000	48	9.94%
Income Source	Business	198	40.99%
	Farming	136	28.16%
	Employed	149	30.85%

Table 1 provides the depiction of customer demographics based on different variables. The gender distribution shows that 54.45% of customers are male, while 45.55% are female. In terms of age, 37.68% of customers fall within the 18-30 years, 50.10% are between 31-50 years, and 12.22% are above 50 years of age. Academic status indicates that 39.96% of customers have completed their school education, 28.78% have completed their undergraduate studies, and 31.26% have completed post-graduate education. Examining the income segment, it is evident that 73.91% of customers have an income below Rs.30,000, 16.15% fall within Rs.30,000-50,000 range, and 9.94% have an income above Rs.50,000. In terms of income source, 40.99% of customers are involved in business, 28.16% are engaged in farming, and 30.85% are employed in either private or government organizations.

Causal Relationship among Research Constructs

The study tests the causal relationship among several variables, namely physical presence (PPNC), product supremacy (PSPM), customer recognition (CREC), store reputation (SRPT), perceived service quality (PSQT), buying intention (BYIN). These variables are examined using a range of observed and unobserved variables. The observed, endogenous variables include PPNC1, PPNC2, PPNC3, PPNC4, PSPM1, PSPM2, PSPM3, PSPM4, CREC1, CREC2, CREC3, CREC4, SRPT1, SRPT2, SRPT3, SRPT4, BYIN1, BYIN2, BYIN3, BYIN4, BYIN5, PSQT1, PSQT2, PSQT3, PSQT4, and PSQT5. On the other hand, the unobserved, endogenous variables consist of SRPT, BYIN and PSQT. Additionally, there are unobserved, exogenous variables denoted as e1 to e29, as well as PPNC, PSPM, and CREC. The model under examination comprises a total of 61 variables, including 26 observed and 35 unobserved

variables. Of these, 32 are exogenous variables, while 29 are endogenous variables. The structural equation model representing the relationships between these variables is presented in Figure 2, and the specific paths and relationships are outlined in Table 2.

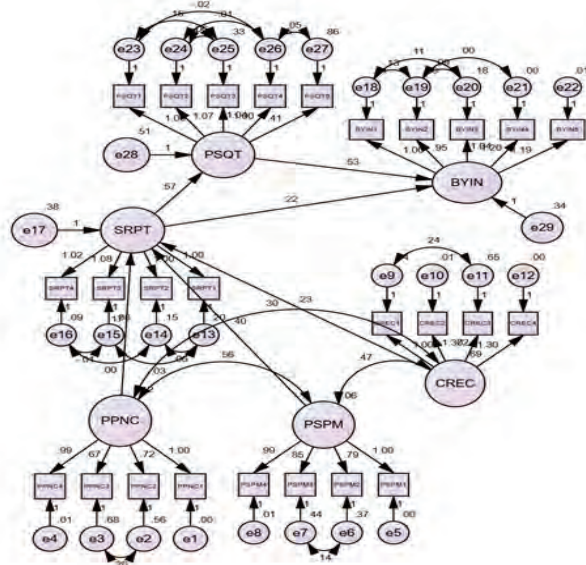


Fig. 2: Structural Equation Model

Table 2: Path Relationship

Path			Raw Estimate	Std. Estimate	t	p
PPNC1 - Cleanliness and layout of store	<---	PPNC	1.000	1.000		
PPNC2 - Sharing experiences and examine products	<---		.716	.712	22.211	***
PPNC3 - Social engagement and personalized interactions	<---		.668	.650	18.758	***
PPNC4 - Product arrangement and display is admirable	<---		.989	.996	202.347	***
PSPM1 - Reasonable worth and good quality of product	<---	PSPM	1.000	1.000		
PSPM2 - Unexpected product variations	<---		.788	.801	29.305	***

PSPM3 - Supply of product is uniform in all seasons	<---		.848	.796	28.810	***
PSPM4 - Select from array of collections	<---		.995	.996	221.111	***
CREC1 - Customer value and welfare is more	<---	CREC	1.000	.651		
CREC2 - Proper care on customer request	<---		1.298	.996	18.772	***
CREC3 - Personnel interaction is gorgeous	<---		.720	.596	14.780	***
CREC4 - Complaint rectification is satisfactory	<---		1.295	.998	18.781	***
SRPT1 - Timely resolution of customer issues	<---	SRPT	1.000	.896		
SRPT2 - Attention on customer service	<---		1.002	.919	36.665	***
SRPT3 - Sale of quality and branded products	<---		1.077	.961	30.501	***
SRPT4 - Ethical practices	<---		1.024	.952	29.725	***
PSQT1 - Timely assistance and behaviour of staff	<---	PSQT	1.000	.787		
PSQT2 - Responsiveness to customer needs	<---		1.066	.879	17.344	***
PSQT3 - In-store support and assured service	<---		1.042	.848	22.877	***
PSQT4 - Clear signage and easy navigation	<---		.996	.869	17.961	***
PSQT5 - Amenities provided in the store	<---		.407	.359	7.601	***
BYIN1 - Assortment and availability of products	<---	BYIN	1.000	.833		

BYIN2 - Comparatively reasonable price charged	<---		.951	.788	27.014	***
BYIN3 - High-quality products marketed	<---		1.037	.897	35.934	***
BYIN4 - Suitable products and convenient to buy	<---		1.198	.998	32.845	***
BYIN5 - Satisfied and loyal service	<---		1.195	.997	32.799	***
SRPT	<---	PPNC	.170	.200	5.263	***
SRPT	<---	PSPM	.402	.460	10.505	***
SRPT	<---	CREC	.227	.211	5.183	***
PSQT	<---	SRPT	.571	.586	11.971	***
BYIN	<---	SRPT	.215	.232	5.312	***
BYIN	<---	PSQT	.530	.557	10.877	***

In the subsequent phase, the fitness index values for the structural model are computed. The results indicate that the model fits the data exceptionally well. The CMIN/df value of 3.227 is in the standard threshold of 3 - 5, indicating a favorable fit. Similarly, the RMSEA value of 0.058 is lesser than the benchmark level of 0.06, assuring strong evidence of model fit. Additionally, several measures of baseline comparisons and goodness of fit ensure additional support for the model adequacy. Accordingly, the GFI (0.901), AGFI (0.903), NFI (0.954), CFI (0.968), IFI (0.968), RFI (0.946), and TLI (0.962) all exceed the minimum requisite of 0.9. Collectively, these values strengthen the notion that the structural model exhibits a perfect fit with the data.

It is evident from table 2, the p-values linked with all paths connecting the research constructs such as, physical presence, product supremacy, customer recognition, store reputation, perceived service quality, and buying intention are statistically significant at 1%. It strongly accepts hypothesis (H1.1), hence, antecedents have positive and significant effect on research constructs. The cleanliness and layout of a physical store play a significant role in establishing its reputation and influencing buying intentions, while social engagement and personalized interactions have a lesser impact. The primary factors contributing to product superiority are reasonable worth and good quality, while the availability of products throughout the year has the least influence. When it comes to customer recognition, prioritizing their requests is considered the most important, whereas personal interactions are given less importance. The sale of high-quality and branded products holds a high rank in store reputation, whereas resolving customer issues in a timely manner ranks lower.

Being responsive to customer needs is a crucial aspect of perceived service quality, whereas the behavior and timely assistance provided by staff have a lesser impact. The most influential factors in shaping buying intentions in retail shops are offering suitable products and providing convenience in the purchasing process, whereas charging a comparatively reasonable price has a lower influence.

The results support hypothesis (H1.2) by demonstrating the significant influence of physical presence, product supremacy, and customer recognition on the store reputation of retail shops. The coefficients indicate that a one-unit increase in physical presence leads to a 0.170-unit increase in store reputation. Similarly, a one-unit increase in product supremacy results in a 0.402-unit increase, and a one-unit increase in customer recognition leads to a 0.227-unit increase in store reputation. The p-values for physical presence, product supremacy, and customer recognition are statistically significant at the 1% level, confirming that physical presence, product supremacy and customer recognition have positive and significant effect on store reputation. Therefore, physical presence, product supremacy and customer recognition all play a significant role in shaping the store reputation to the retail shops. Furthermore, the coefficients representing the impact of store reputation on buying intention indicate that a one-unit increase in store reputation leads to a 0.238-unit increase in buying intention. This confirms hypothesis (H1.3) and signifies that store reputation has a positive and significant effect on buying intention. Thus, it is confirmed that the combined effects of physical presence, product supremacy and customer recognition significantly influence the store reputation of retail shops, ultimately leading to improve buying intention among customers.

Mediating Effect of PSQT on SRPT and BYIN

Perceived service quality of retail shops is a significant factor that mediates between store reputation and buying intention. When customers visit a retail shop, their perception of the service quality provided by the store plays a crucial role in determining their overall satisfaction and, consequently, their intention to make a purchase. As a result, understanding and effectively managing the mediating role of perceived service quality in the relationship between store reputation and buying intention is crucial for retailers in order to cultivate positive customer experiences and drive business success. Therefore, mediating effect of perceived service quality of retail shops are taken into account. Consequently, the hypothesis (H1.4) asserts that perceived service quality has mediating effect between store reputation and buying intention.

Table 3: Mediating Effect of PSQT on SRPT and BYIN

Effect	Path		Estimate	p
Mediation – Path A	PSQT	<--- SRPT	.571	***

Direct	BYIN	<---	SRPT	.215	***
Mediation – Path B	BYIN	<---	PSQT	.530	***

Table 3 illustrates the direct and indirect relationship between store reputation, perceived service quality, and buying intention. The direct impact of store reputation on buying intention is measured at 0.215. To assess the mediating effect, it is considered the influence values of 0.571 from store reputation to perceived service quality and 0.530 from perceived service quality to buying intention. Consequently, these values are multiplied, resulting in a calculated mediation value of 0.30263, indicating an overall impact of 0.51763. The variance associated with this value is determined to be 0.5846. Since the variance exceeds 0.2, it endorses a strong partial mediation. Based on these findings, it can be concluded that the perceived service quality acts as a partial mediating factor between store reputation and the buying intention of customers in retail shops.

Demographic Characteristics Impact on Research Constructs

The impact of demographic characteristics on research constructs is tested with Anova. The hypothesis (H1.5) asserts that demographic characteristics have significant impact on research constructs.

Table 4: Anova

Research Constructs	Age		Academic Status		Income Segment		Income Source	
	F	Sig.	F	Sig.	F	Sig.	F	Sig.
Physical Presence	232	.793	3.204	.041**	11.003	.000**	106	.899
Product Supremacy	1.478	.000**	5.456	.005**	12.212	.000**	464	.629
Customer Recognition	.151	.000**	6.884	.001**	11.945	.000**	196	.822
Store Reputation	.139	.002**	2.350	.096	12.780	.000**	578	.561
Perceived Service Quality	.223	.109	6.095	.002**	16.097	.000**	723	.486
Buying Intention	.720	.004**	2.438	.088	8.377	.000**	.422	.514

*** Significance level at 1%, ** Significance level at 5%

Table 4 depicts that the computed Anova values for age, academic status, income segment and income source. Age has significant impact on product supremacy, customer recognition, store reputation and buying intention, whereas, results are insignificant to physical presence and perceived service quality. Duncan's post-hoc test formed two

equivalent sub-groups like, 31 – 50 years in sub-group a; and 18 – 30 years and above 50 years in sub-group b for products supremacy and customer recognition. Similarly, it formed two equivalent sub-groups like, 31 – 50 years and 18 – 30 years in sub-group a; and above 50 years in sub-group b for store reputation and buying intention. Academic status has significant impact on physical presence, product supremacy, customer recognition, and perceived service quality, whereas, results are insignificant to store reputation and buying intention. Gabriel's post-hoc test formed three equivalent sub-groups like, undergraduate in sub-group a; school in sub-group a, b and post graduate in sub-group b for physical presence. It formed two equivalent sub-groups like, undergraduate in sub-group a; and post graduate and school in sub-group b for products supremacy and customer recognition. It also formed two equivalent sub-groups like, undergraduate and school in sub-group a; and post graduate in sub-group b for perceived service quality. Income segment has significant impact on physical presence, product supremacy, customer recognition, perceived service quality, store reputation and buying intention. Ryan-Einot-Gabriel-Welch Range's post-hoc test formed three equivalent sub-groups like, below Rs.30,000 in sub-group a; Rs.30,000-50,000 in sub-group b; and above Rs.50,000 in sub-group c for store reputation. It also formed two equivalent sub-groups like, below Rs.30,000 and Rs.30,000-50,000 in sub-group a; and above Rs.50,000 in sub-group b for physical presence, product supremacy, customer recognition, perceived service quality and buying intention. Income source has no significant impact on research constructs.

DISCUSSION AND CONCLUSION

The study investigated the mediating effect of perceived service quality on the relationship between store reputation and buying intention of customers in retail shops. The study established a positive and significant relationship between store reputation and perceived service quality. This implies that customers perceive retail shops with a good reputation to provide high-quality services. Retailers need to focus on building and maintaining a positive reputation to enhance customers' perception of service quality. The study revealed a positive and significant relationship between perceived service quality and buying intention. This indicates that customers who perceive higher service quality in a retail shop are more likely to have a stronger intention to make purchases. Retailers should strive to improve service quality through various means, such as staff training, personalized customer experiences, and efficient service delivery, to positively influence customers' buying intention. The mediating role of perceived service quality was confirmed in the relationship between store reputation and buying intention. This implies

that perceived service quality acts as a crucial mechanism through which store reputation affects customers' buying intention. A good reputation alone may not directly translate into increased buying intention, but it indirectly influences it by shaping customers' perception of the service quality offered. Based on these findings, it is evident that retail shops should prioritize building a strong reputation while simultaneously focusing on delivering exceptional service quality. As a consequence, retailers can positively influence customers' buying intention, thereby increasing sales and fostering customer loyalty. Additionally, retailers should continuously monitor and improve their service quality to maintain a positive reputation and sustain customers' buying intention in the long term.

Physical presence, product supremacy and customer recognition have significant impact on forming store reputation of retail shops. Customers are paying much more interest towards presence of stores, originality of products and gratitude given to the customers. The results reveal that store reputation has a significant positive impact on buying intention of customers towards retail shops. Furthermore, perceived service quality was found to partially mediate the relationship between store reputation and buying intention. A positive perception of service quality enhances store reputation, as customers associate it with a high level of professionalism, customer care, and product offerings. This positive reputation, in turn, strengthens customers' buying intentions as they develop trust and confidence in the store. On the other hand, a negative perception of service quality can lead to a decline in store reputation and lower buying intentions, as customers may question the reliability and value of the products and services offered. It suggests that customers' perceptions of service quality play a crucial role in influencing their purchase decisions in retail shops. The findings also designate that demographic characteristics, such as age, academic status, and income, have significant impact on the research constructs. The findings suggest that retail shops should prioritize building and maintaining a positive store reputation to enhance perceived service quality, which, in turn, can positively influence customers' buying intention.

PRACTICAL IMPLICATIONS

The findings of this study are expected to have practical implications for retail shop managers and marketers. By identifying the specific dimensions of perceived service quality that mediate the relationship between store reputation and buying intention, retailers can develop targeted strategies to enhance their overall service quality and strengthen their reputation. This, in turn, can lead to increased customer satisfaction, loyalty, and ultimately, higher buying intention. Overall, investigating the mediating effect of perceived

service quality on store reputation and buying intention contributes to the existing body of knowledge in the field of consumer behavior and provides valuable insights for retailers aiming to optimize their marketing strategies and improve their competitive advantage in the dynamic retail landscape.

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Assessing the Financial Impact of COVID-19 on Island Tourism Enterprises: Evidence from Travel Agents in Andaman

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ABSTRACT

This is quite known to every individual how COVID-19 had an impact on the economy, people, and society. The negative and positive effects of the COVID-19 lockdown may not be ignored ever in life. The entire tourism industry especially the tour and travel agents was the worst affected by the COVID-19 lockdown in Andaman and Nicobar Islands. The study was based on the primary data of 85 sample respondents (tour and travel agents) in the South Andaman district of Andaman and Nicobar Islands, simple random sampling technique was adopted to gather information through a structured interview schedule. The study results completely agreed that the tour and travel agents had faced several economic issues during the period of the COVID-19 lockdown. The hypotheses were framed to test the mean differences of several before and after lockdown economic variables and the test results revealed that there are significant differences in all the economic variables. The Administration of Andaman and Nicobar Islands and the tourism stakeholders need to cooperate all the time whenever needed especially in emergencies. The study has provided valuable suggestions to the administration and tour and travel agents to minimize the disparities that occur during any natural calamities.

KEYWORDS : *Tour and travel agents, Andaman and Nicobar islands, Lockdown, COVID-19, Tourism.*

INTRODUCTION

According to the report of the WTTC, the pandemic had a considerable impact on tourism around the world. In 2020, travel and tourism are facing a potential job loss of up to 75 million in addition to \$2.7 trillion in revenue. The government supports health and safety strategies as part of recovery protocols (WTTC, 2020). A series of reports on the impact of COVID-19 on tourism in Europe have been released by the European Commission, focusing on the sharp drop in tourist arrivals and the economic damage to local enterprises. They also give guidelines for improving recovery and resilience (European Commission, 2020). On the basis of this estimate, COVID-19 has already caused significant disruption to Australia's tourism industry in domestic and international travel and has lost \$80 billion of tourism revenue (Australian Government, 2020). The impacts of COVID-19 on global tourism are discussed in the IMF report, with particular attention to the economic implications for developing and emerging economies. It insists on how the pandemic influenced the countries that relied on tourism and strengthened income inequality (IMF, 2020). The paper reports on the reduction in international

tourist arrivals to the US in response to COVID-19 and the resultant macroeconomic consequences. It also analyses domestic tourism trends, and the slow recovery of 2021 and 2022 (NTTO, 2020).

RESEARCH GAP

There are extremely rare studies that covered the basic problems of travel agents or the tourism industry during the COVID-19 lockdown. However, studies on the economic conditions of tour and travel agents during the COVID-19 lockdown have not been done so far in terms of economic loss or changes that happened during the period of COVID-19 lockdown of tour and travel agents in Andaman and Nicobar Islands.

RESEARCH OBJECTIVES

- To analyze the economic losses incurred by the tour and travel agents during the period of the COVID-19 lockdown in Andaman and Nicobar Islands.
- To provide valuable suggestions for the administration and tourism stakeholders to avoid or minimize the disparities that occur during any natural calamities.

RESEARCH HYPOTHESIS

The research hypotheses were framed to test the significant pre and post-COVID-19 lockdown economic differences. Since the economic loss or negative effects on the business during the time of lockdown were normal, the test was performed to examine whether the situation became normal or not after the COVID-19 lockdown. Since the responses had been recorded in the ranges of different economic variables, the midpoint-based method has been adopted to calculate the actual mean and test the research hypotheses.

Sl. No.	Null Hypothesis (H0)	Alternative Hypothesis (H1)
1.	There is no significant mean difference between the before and after lockdown monthly income of tour and travel agents.	There is a significant mean difference between the before and after lockdown monthly income of tour and travel agents.
2.	There is no significant mean difference between the before and after lockdown monthly family expenditure of tour and travel agents.	There is a significant mean difference between the before and after lockdown monthly family expenditure of tour and travel agents.
3.	There is no significant mean difference between the before and after lockdown monthly operating expenditure of tour and travel agents.	There is a significant mean difference between the before and after lockdown monthly operating expenditure of tour and travel agents.
4.	There is no significant mean difference between the before and after lockdown monthly maintenance costs of tour and travel agents.	There is a significant mean difference between the before and after lockdown monthly maintenance costs of tour and travel agents.
5.	There is no significant mean difference between the before and after lockdown monthly bank money withdrawals of tour and travel agents.	There is a significant mean difference between the before and after lockdown monthly bank money withdrawals of tour and travel agents.
6.	There is no significant mean difference between the before and after lockdown bank savings of tour and travel agents.	There is a significant mean difference between the before and after lockdown bank savings of tour and travel agents.

METHODOLOGY

The research was conducted in the South Andaman districts of the Andaman & Nicobar Islands. In order to gather data from the respondents, a semi-structured interview schedule was developed and the primary data were collected from 85 tour and travel agents (samples) from the entire South Andaman

area. A simple random sampling technique was employed in this research to give an equal chance to the respondents. This study primarily examines three distinct phases of economic loss and changes due to the COVID-19 lockdown: pre-lockdown, during lockdown, and post-lockdown. SPSS 25 was performed to analyze the data. The student's t-test has been performed to examine the differences in the pre and post-COVID-19 lockdown based on the midpoints of the different economic variables to consider as the actual value of the variables that influenced the changes in the business of the tour and travel agents of Andaman and Nicobar Islands. The null hypotheses of the research are accepted or rejected based on the p-value approach.

RESULTS AND DISCUSSION

Demographic details of the Respondents

The results indicate that all the sample respondents are from Port Blair, South Andaman, and there is no representation from other areas. Also, all the sample respondents live in urban areas, with no one living in rural areas. For gender, the sample is 100 percent male due to the unavailability of female respondents in the tour and travel agencies in the sample study area. The highest age group is 32-42 years, which constitutes 62.4 percent of the sample. Religiously, 71.8 percent are Hindu, followed by 15.3 percent are Christian and 12.9 percent are Muslim. In terms of community, 50.6 percent are from the OBC category and 49.4 percent are from the General category. In terms of marital status, 85.9 percent are married and 14.1 percent are unmarried. Regarding the type of family, 54.1 percent of the respondents were from nuclear families and 45.9 percent were from joint families. With respect to education, 74.1 percent have passed a diploma or graduation, whereas 25.9 percent have passed higher secondary education (11th-12th std.). This indicates comparatively educated, married, and largely Hindu respondents with a slight inclination towards nuclear families.

Type of agency, the residence, and rent

According to the data, 24.7 percent of the sample utilized exclusively offline travel agencies, while 75.3 percent of the sample used both online and offline travel agencies before, during, and after the COVID-19 lockdown. This implies that, probably as a result of changing patterns of travel throughout the pandemic, most people kept using a hybrid model of travel firms that provided both online and offline services. A large percentage of the sample (72.9 percent) resided in rented houses before, during, and after the COVID-19 lockdown, whereas 27.1 percent were owners of the house. This suggests that most people do not own houses, which could be an expression of a preference for renting or the

freedom it provides, especially during the uncertainty of the pandemic. The majority of respondents (38.8%) had a rent for their residence between Rs. 6,000 and Rs. 10,000 monthly, followed by 32.9% paying rent between Rs. 11,000 and Rs. 15,000. Just 1.2% of the respondents spend more than Rs. 15,000 on monthly rent. This points to the fact that the majority of the respondents had moderate rent payments with fewer in the higher rental bracket, and all the respondents paid rent before, during, and after the COVID-19 lockdown.

Type of agency, the residence, and rent

A majority of the respondents (61.2%) made an investment of Rs. 6,00,000 to Rs. 10,00,000 in their business, followed by 29.4% who made an investment of Rs. 11,00,000 to Rs. 15,00,000. A mere 9.4% of the respondents considered an investment of over Rs. 15,00,000. This reflects that the majority of people were considering moderate to large-scale investments in their businesses before the lockdown. The study shows that all (100%) the respondents possess an insurance policy for their travel vehicles. It illustrates that each one of them has insured their travel vehicles. Each respondent possesses an insurance policy for their travel vehicles with a cover value of greater than Rs. 15,000. This shows that each respondent has taken travel vehicle insurance with an amount of premium higher than Rs. 15,000. 68.2% of the respondents kept paying the same amount for their travel vehicle insurance throughout the Corona period, and 31.8% did not. This indicates that most people maintained their insurance payments throughout the pandemic, while a smaller percentage did not. The data indicates that those who did not pay the same amount for their travel vehicle insurance during Corona time, mentioned that the insurance was “not needed during Corona.” No other reason is given.

Dedicated office space and the office rent

44.7% of the respondents had a separate office space for their travel agency during the lockdown, and 55.3% did not. All the separate offices were rented and the data shows that out of the 44.7% of the respondents who rented an office for their travel agency, most (25.9%) paid between Rs. 6,000 and Rs. 10,000 as rent. Most respondents had difficulty making rent payments for the rental office during the lockdown, probably due to financial hardships brought about by the pandemic.

Monthly Income and Family Expenditure

Prior to the lockdown, 69.4% of the respondents earned between Rs. 41,000 and Rs. 60,000, and 30.6% earned above Rs. 60,000. But post-lockdown, 67.1% of the respondents earned between Rs. 21,000 and Rs. 40,000, and just 32.9% earned between Rs. 41,000 and Rs. 60,000. This indicates a substantial decline in income for most travel agencies due to

the impact of the lockdown, with many seeing their income drop to lower ranges. A sharp rise in family spending both during and post-lockdown. Prior to the lockdown, the majority of families used to spend between Rs. 21,000 and Rs. 30,000, but during the lockdown, more families (49.4%) spent more than Rs. 30,000. This also happened post-lockdown, where more families (56.5%) continued to spend more than Rs. 30,000, even after the financial pressures due to lowered incomes during the pandemic. This indicates that families incurred higher costs, possibly from increased expenses or lifestyle changes prompted by the lockdown

Monthly Operational and Maintenance Cost in the Business

The cost of operations rose after the lockdown. Prior to the lockdown, the majority of firms (69.4%) experienced lower operational costs, between Rs. 11,000 and Rs. 20,000. After the lockdown, a greater percentage of businesses (48.2%) experienced higher operational costs, between Rs. 21,000 and Rs. 30,000, and 23.5% had expenses above Rs. 30,000. This shift suggests that the lockdown likely led to higher operational challenges and expenses, which may have been due to adjustments made in response to the pandemic. The cost of maintenance increased during and after the lockdown. Prior to the lockdown, the majority of firms (58.8%) had modest expenditure on maintenance between Rs. 11,000 and Rs. 20,000. After the lockdown, however, there was a movement towards a higher expenditure category, with 43.5% now spending Rs. 21,000 to Rs. 30,000. The rise in maintenance expenditure may be associated with increased costs due to adjustments in operations or pressure from inflation during the pandemic.

Bank Debt and its EMI for the Business

All travel agents had a debt with the bank and were paying monthly installments. Before the lockdown, most agents had owed between Rs. 5,00,000 and Rs. 12,00,000 from the bank. Before and even during the lockdown, the majority were paying around Rs. 6,000 to Rs. 10,000 in EMI installments. Yet, most payments (75%) were finding it difficult to pay EMI installments during the lockdown, where many were paying EMI over Rs. 15,000 altogether. Following the lockdown, most agencies restarted their earlier EMI payments despite the financial hardship, reflecting a persistent financial strain caused by outstanding financial obligations. A majority of 85.9% of travel agents were unable to meet their bank debt EMIs during the COVID-19 lockdown. The major cause for this was the total loss of income (78.8%), indicative of the devastating impact the pandemic had on them. A lesser percentage of agents (7.1%) experienced inadequate earnings, further showing the financial burden felt throughout the sector during this period.

Monthly bank account money withdrawals

The economic stress was realized during the time of lockdown when there was an immense surge in monthly withdrawals in banks. Initially, before lockdown, most of the agents made between Rs.21,000 and Rs.30,000, but for those in the time of lockdown, most made above Rs.30,000 in order to meet basic necessities. After the lockdown, a bit of a recovery trend came to life, although the withdrawals stayed higher than their pre-pandemic levels, implying that recovery time was also stressing the economy.

Business loss and loss of savings

The study indicates that the lockdown had a disastrous effect on the travel agency business. Prior to the lockdown, there were no loss reports, but during the lockdown, the majority of the agents lost over 75% of their business. After the lockdown, 88.2% of agents recorded business losses of 51% to 75%, which meant that the recovery was sluggish and that a majority of the travel agency industry was still struggling even after the end of the lockdown. A steep decline in savings of travel agents due to the COVID-19 lockdown. Most of them had savings ranging between Rs.4,00,000 and Rs.6,00,000 prior to the lockdown, whereas during and even after the lockdown, most had considerably lower savings. To be precise, 56.5% of agents had savings up to Rs.3,00,000 after the lockdown, indicating that many were cash-strapped because of the long-drawn effect of the pandemic on their business.

Support and Assistance for the Travel Agents

Although travel agents did not gain any financial or NGO support directly during the lockdown, the vast majority (85.9%) experienced some benefit from EMI debt relaxation, which enabled them to postpone repayment schedules of their loans. It appears that though direct money support was not forthcoming, the government did provide some kind of relief in the form of easing debt payments.

Alternative Employment and Basic Necessities

Most travel agents did not look for alternative employment or relocate for new job opportunities during the lockdown. Meanwhile, they experienced difficulties with higher prices of everyday commodities (mainly 11% to 20% increase in the price) and shortages of goods and services in the market. These added to the financial hardships already presented by the pandemic.

Help and Support required during the COVID-19 lockdown

In times of emergency, most of the respondents were seeking monetary assistance, and a large percentage also needed

provisions on a day-to-day basis to sustain their family's livelihood needs, illustrating the complex nature of the support needed in times of crisis.

Paired Sample t-Test Results of Research Hypotheses

Table 7.1 (a) the t-statistics of before and after COVID-19 Lockdown mean difference of monthly income

	Periods	Cor.	Mean	S.D	S.E	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
						Lower	Upper			
Pair 1	Monthly Income Before Lockdown	.839	19529.41	5324.22	577.49	18381.00	20677.81	33.818	84	.000
	Monthly Income After Lockdown									

*Cor.- Correlation, S.D- Standard Deviation, S.E- Standard Error of Mean, df-Degree of Freedom, Sig.- Significant

The above table 7.1 (a) reveals that there is a significant mean difference between the before and after lockdown monthly income of tour and travel agents. Hence, the calculated value is less than (.000<0.05) the alpha value, and the null hypothesis "There is no significant mean difference between the before and after lockdown monthly income of tour and travel agents" is rejected at a 5 percent level of significance and the alternative hypothesis is accepted.

Table 7.1 (b) the t-statistics of before and after COVID-19 Lockdown mean difference of monthly family expenditure

	Periods	Cor.	Mean	S.D	S.E	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
						Lower	Upper			
Pair 2	Monthly Family Expenditure Before Lockdown	.698	-6823.52	4683.24	-507.96	-7833.68	-5813.37	-13.433	84	.000
	Monthly Family Expenditure After Lockdown									

*Cor.- Correlation, S.D- Standard Deviation, S.E- Standard Error of Mean, df-Degree of Freedom, Sig.- Significant.

The above table 7.13 (b) exposes that there is a significant mean difference between the before and after lockdown monthly family expenditure of tour and travel agents. Hence, the calculated value is less than ($.000 < 0.05$) the alpha value, and the null hypothesis “There is no significant mean difference between the before and after lockdown monthly family expenditure of tour and travel agents” is rejected at a 5 percent level of significance and the alternative hypothesis is accepted.

Table 7.1 (c) the t-statistics of before and after COVID-19 Lockdown mean difference of monthly operational cost

	Periods	Cor.	Mean	S.D	S.E	95% Confidence Interval of the Difference		t	d f	Sig. (2-tailed)
						Lower	Upper			
Pair 3	Monthly Operational Cost Before Lockdown	.755	-6470.58	4807.20	521.41	-7507.47	-5433.69	-12.410	84	.000
	Monthly Operational Cost After Lockdown									

*Cor.- Correlation, S.D- Standard Deviation, S.E- Standard Error of Mean, df-Degree of Freedom, Sig.- Significant

The above table 7.1 (c) declares that there is a significant mean difference between the before and after lockdown monthly operating expenditure of tour and travel agents. Hence, the calculated value is less than ($.000 < 0.05$) the alpha value, and the null hypothesis “There is no significant mean difference between the before and after lockdown monthly operating expenditure of tour and travel agents” is rejected at a 5 percent level of significance and the alternative hypothesis is accepted.

Table 7.1 (d) the t-statistics of before and after COVID-19 Lockdown mean difference of monthly maintenance costs

	Periods	Cor.	Mean	S.D	S.E	95% Confidence Interval of the Difference		t	d f	Sig. (2-tail ed)
						Low er	Upp er			
Par 4	Monthly Maintenan e Cost Before Lockdown	.794	-6941.17	4635.14	502.75	-7940.95	-5941.39	-13.806	84	.000
	Monthly Maintenan e Cost After Lockdown									

*Cor.- Correlation, S.D- Standard Deviation, S.E- Standard Error of Mean, df-Degree of Freedom, Sig.- Significant

The above table 7.13 (d) exhibits that there is a significant mean difference between the before and after lockdown monthly maintenance costs of tour and travel agents. Hence, the calculated value is less than ($.000 < 0.05$) the alpha value, and the null hypothesis “There is no significant mean difference between the before and after lockdown monthly maintenance cost of the tour and travel agents” is rejected at a 5 percent level of significance and the alternative hypothesis is accepted.

Table 7.1 (e) the t-statistics of before and after COVID-19 Lockdown mean difference of monthly bank money withdrawals from the bank

	Periods	Cor.	Mean	S.D	S.E	95% Confidence Interval of the Difference		t	d f	Sig . (2-tail ed)
						Lo wer	Up per			
Pair 5	Monthly Money Withdraw als Before Lockdown	.601	-1411.76	3502.70	379.92	-2167.27	-656.24	-3.716	84	.000
	Monthly Money Withdraw als After Lockdown									

*Cor.- Correlation, S.D- Standard Deviation, S.E- Standard Error of Mean, df-Degree of Freedom, Sig.- Significant

The above table 7.13 (e) discloses that there is a significant mean difference between the before and after lockdown monthly bank money withdrawals of tour and travel agents. Hence, the calculated value is less than ($.000 < 0.05$) the alpha value, and the null hypothesis “There is no significant mean difference between the before and after lockdown monthly bank money withdrawals of tour and travel agents” is rejected at a 5 percent level of significance and the alternative hypothesis is accepted.

Table 7.1 (f) the t-statistics of before and after COVID-19 Lockdown mean difference of bank savings

	Periods	Cor.	Mean	S.D	S.E	95% Confidence Interval of the Difference		t	d f	Sig. (2-tailed)
						Lower	Upper			
Pair 6	Bank Savings Before Lockdown	.739	222352.94	132176.35	14336.53	193843.16	250862.71	15.510	84	.000
	Bank Savings After Lockdown									

*Cor.- Correlation, S.D- Standard Deviation, S.E- Standard Error of Mean, df-Degree of Freedom, Sig.- Significant.

The above table 7.1 (f) unveils that there is a significant mean difference between the before and after lockdown bank savings of tour and travel agents. Hence, the calculated value is less than ($.000 < 0.05$) the alpha value, and the null hypothesis "There is no significant mean difference between before and after lockdown bank savings of tour and travel agents" is rejected at a 5 percent level of significance and the alternative hypothesis is accepted

CONCLUSION

Tourism of Andaman and Nicobar Islands is still in an initial stage and slowly it started heading towards development. The tourism industry of Andaman and Nicobar Islands is the biggest source of income for the many youths and Islanders and tourism is even fragile if it is not taken care of extensively. There were many disasters faced by the different parts of the Islands and the players of the tourism. However, the COVID-19 effect was the one that can never be forgotten, study has chosen to find the effectiveness of the COVID-19 lockdown on the tour and travel agents of South Andaman district. The study emphasized finding the several types of economic loss incurred by the tour and travel agents and based on the results of the study, valuable suggestions have been provided to the administration and stakeholders of Andaman and Nicobar Islands. The tour and travel agents suffered financially in different scenarios for several months (till the pandemic period was completely over) and it has been revealed that there is a significant difference in the before and after lockdown various economic variables of the tour and travel agents. The study even revealed that the income was zero but the expenditures for survival and the inactive business maintenance increased during the period of lockdown.

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Decreasing Stress Improves the Work-Life Balance of Private Colleges' Staffs - A Conceptual Study

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ABSTRACT

Any alteration that strains the body, mind, or emotions counts as broad term for stress. The body's response indicates that stress calls either concentration or action. Everybody goes through demanding periods. Still, your general health is much influenced by your attitude to stress. Stress during this time arises in all kind of employment. Not stressed out employees are quite rare. Workers are compelled to properly balance their job with their personal lives. The results of this study indicate that reduced stress among staff members of private colleges is a factor motivating to preserve work-life balance. This study has also shown this by adjusting elements that gauges work-life balance and proving that improved work-life balance results from less stress. In this scenario, objective criteria helped to compile the material. Convenient sampling helped the data to be gathered. The sample consisted of just 72 staff members from different private universities in Thanjavur, Tamil Nadu. Direct gathering of the data came by answering a questionnaire. Measured Structural Equation Model (MSEM) analysis using application AMOS software (version 24) is conducted in this work. Measured Structural Equation Model (MSEM) with the AMOS program (version 24) guides the research design. With a few key criteria—CMIN/df, RMSEA, CFI, TLI, and GFI—the MSEM was evaluated; the first two fell within a reasonable range and the rest of them were sufficient to accept the model. This study implies that by lowering stress, assistant professors employed at private institutions find their work-life balance to become stable. According to this study, elements that help to reduce stress were most suited for stability of work-life balance. Academic institutions should create a thorough strategy to organise and apply techniques for helping their staff in managing their work-life balance, thereby improving the performance of their personnel by addressing the relevant issues influencing their workforce. The study shows the theory is disproved. Therefore, the study advised the government to provide surroundings where teachers may operate totally stress-free. This study implies generally further comprehensive investigation on this subject.

KEYWORDS : *Decreasing stress, Improves, Work-life balance, Private colleges staffs, Personal commitment, Job satisfaction.*

INTRODUCTION

Stress is something that clutches our brains and prevents daily peace from being our constant state. In the era of today, how many advancements have occurred? There is something to wonder at everywhere the globe is running after. Development in science and technology is positive. Business contacts are a daily growing source from which

nothing runs short. Travelling in such a busy environment, people are sprinting very fast to raise their quality of living and economy. Men yearning for anything and travelling somewhere originate from stress at work, improper family care, and disrespect of their own tastes and dislikes. Many people deal with stress without finding release. Good workers are those who show conscientious effort and responsibility at the job. Still, they cannot effectively run the family.

Likewise, those who have good family management find it difficult to concentrate on their work to perform effectively at their offices. A good work-life balance is not shared by very many people. The results of this study indicate that reduced stress among staff members of private colleges is a factor motivating to preserve work-life balance. This study has also shown this by changing elements that gauges work-life balance and proving that better work-life balance results from reduced stress.

STATEMENT OF THE PROBLEM

Subbarayalu, Prabakaran and Devalapalli (2021) claimed that regardless of the kind of business people operate in, one of the main criteria for the quality of their work-life is their balance between it. They also imply that conflict could have two roots that are Work-life conflict is the result of job interfering with family life (work-to--family conflict) and family life interfering with job (family-to--work conflict).

Chandrakala DP, Sushma B S, and Vanishree K (2020) imply that among employees, one of the most interesting problems is their work-life balance. For women, ability to manage their personal and professional life is quite crucial. They also propose that the hypothesis test shows that high work pressure resulting from balancing their work-life teaching faculties causes a notable proportion of working women confronting complexity in balancing their personal life.

Haar and Brougham (2020) address concerns in work-life balancing issues and the combining of new antecedents in the modern environment and also suggest that efforts made by employees and companies to improve WLB capacities are expected to have favourable consequences on mental and physical health as well as enhanced job outcomes, including performance. Knowing WLB will become more important since finding a suitable balance in this surroundings becomes more difficult. The present study tackles work-life balance problems and the mix of new antecedents in teaching faculties with the background of their low incomes, hard workloads at private institutions, stress in the workplace, and family conditions. Every employee had their work hours changed in some circumstances, which also resulted in greater family problems. Working environment (Subbarayalu, Prabakaran, & Devalapalli., 2021); beer role (Family Supports); career prospects provided in the working institution (Shiny & Ramkumar, 2021); and present research considers all these antecedents.

OBJECTIVE OF THE STUDY

- Examine the personnel working for private colleges' demographic profile.

- To learn how to lower stress levels,
- To find how less stress enhances work-life balance.
- Analysing the declining stress variables using a demographic profile.

MATERIALS AND METHODS

Collecting and analyzing data

- Information was supplied by staff members of private colleges using a straightforward sampling technique.

Distribution of Questionnaires

Teachers of private colleges were asked using a questionnaire approach. Regarding primary data, we have compiled responses from 72 Thanjavur District teaching faculties from different institutions.

- In this scenario, objective criteria helped to compile the material.
- Convenient sampling helped the data to be gathered.
- The sample consisted of just 72 staff members from different private universities in Thanjavur, Tamil Nadu.
- Direct gathering of the data came by answering a questionnaire.
- Measured Streuctural Equation Model (MSEM) analysis using application AMOS software (version 24) is conducted in this work.

Sampling and study area

This study selected seventy-two college staff members from which replies were examined. The data was gathered conveniently using a sampling technique. A five-point Likert scale helps to examine the facts. Demographic factors were included in analysis of the outcomes.

Table 1 (Demographic Study of the Respondents)

S. No	Demographic Variables	Respondents Category	No. of Respondents	No. of Respondents In Percentage
1	Age	31-40 41-50	42 30	58% 42%
2	Gender	Male Female	36 36	50% 50%
3	Marital status	Single Married	23 49	32% 68%
4	Professional experience	1-5 years 6-10 years	48 24	67% 33%

In this study, 72 employees from various colleges in the Thanjavur region were selected as respondents, 36 of whom

were men and 36 of whom were women. They have been divided into groups based on a variety of demographic characteristics, including age, marital status, gender, and lastly, professional experience.

RESEARCH FRAMEWORK

Fig. 1 Research Framework

RESEARCH HYPOTHESES

Personal Commitment

Lea and Nabo (2023) The work-life balance of faculty members with designations in a few higher education institutions was the main emphasis; also, the study looked at whether the participants' personal and professional profiles showed any noteworthy differences. Their studies turned out that the people had great work-life balance. Their personal and professional profiles did not show any clear variances. The results of the survey revealed that the participants really appreciated keeping work-life balance. The nature of one's job life influences their responsibilities in life; we thus structure that.

H1: Work-life balance is influenced by personal commitment.

H2: Career Development opportunities have positive influence on employees' work-life balance.

H3: Work-life balance and a feeling of security positively influence the work-life balance of the teaching faculties.

H4: Work-life balance is positively influenced by stress-management abilities of teaching faculties.

H5: A positive working environment has improved abilities in faculties and work-life balance capacities.

H6: Work-life balancing abilities are significantly influenced by management policy.

H7: Family Support significantly positively influences work-life balance abilities.

RESULTS

Measured Structural Equation Model (MSEM) with the AMOS program (version 24) guides the research design. With a few key criteria—CMIN/df, RMSEA, CFI, TLI, and GFI—the MSEM was tasted; the first two fell within a reasonable range and the rest of them were decent enough to accept the model. The model's fitness table included:

Table 2 Goodness-of-fit Evaluation

Fit Measure	Value	Goodness-of-fit
CMIN/df	2.186	Acceptable
RMSEA	.167	Acceptable
CFI	.000	Good
TLI	.000	Good
RMR	.236	Good
GFI	.713	Good

Table 3 Hypotheses Results

S. No	Dependent Variable		Independent Variable	Estimate	S.E.	C.R.	P	Result
H1	WLB abilities	<---	personal commitment	.180	.063	2.840	.005	Accepted
H2	WLB abilities	<---	Career development	.227	.063	3.427	.003	Accepted
H3	WLB abilities	<---	job security feelings	-.155	.091	-1.698	.090	Rejected
H4	WLB abilities	<---	stress managing abilities	.075	.070	1.074	.283	Rejected
H5	WLB abilities	<---	Working environment	.050	.059	.850	.396	Rejected
H6	WLB abilities	<---	Management policies	o.116	.068	1.970	.049	Accepted
H7	WLB abilities	<---	Family supports	-.016	.065	-.250	.802	Rejected
H8	WLB abilities	<---	Job satisfaction	.153	.049	2.068	.002	Accepted
H9	WLB abilities		Emotional commitment	.943	.049	1.998	.045	Accepted

DISCUSSIONS

H1 gets approved. Work-life balance (WLB) affects personal commitment (PC); so, data imply that PC significantly effects the WLB of the teachers. H2 is embraced at a 0.00 p value. It implies that good career development might enable teachers to properly control the WLBs and that the road between career growth and WLB capabilities is quite favourable and greatly affects employees's work-life balance..

H3 is denied; the WLB of the teaching staff suffers from unfavourable influence from job security emotions. H4 is likewise rejected; it implies that although the influencing level is not considerable, the stress-managing skills of teaching faculty positively affect work-life balancing ability. H5 is denied, and it implies that WLB should benefit from the development of a workplace. H6 is approved, and findings imply that work-life balance capacity in teaching institutions is much influenced by management practices.

H7 is rejected, and family support has little effect on WLB either. WLB is also abilities, hence worker opinions of family supports vary from one individual to another. H8 is also acknowledged, and employee job happiness affects WLB favourably. H9 is approved, and an emotional dedication to education greatly influences preserving a good work-life balance.

SUGGESTIONS

According to the present study, instructional faculties help managing the work life in a balanced and satisfactory way by means of emotional commitment to the task. One more internal element is the rise in WLB ability brought about by work satisfaction among teachers. According to the current studies, psychological as well as internal elements help instructional faculties to have WLB capacity. Balancing the WLB of teaching faculties also depends much on job-related growth possibilities; personal dedication also helps the WLB capacity of teaching faculties.

Employment stability Emotions exert minimal influence on the work-life balance capabilities of teaching staff, whereas management policies are crucial for employee motivation. The policies should contemplate the incorporation of relaxing techniques, including yoga and meditation. These workouts invigorate the body and lower blood pressure. Initiatives such as complimentary wellbeing exams, wellness protection, and fitness-oriented workplaces profoundly impact instructional personnel who function as exemplary support mechanisms. Establishing coordinating administrations inside their respective organisations through consultants to facilitate staff training in mental and physical rhythm is essential for fitness

centres. Management should cultivate a sense of community among employees and organise stress-relief events such as gatherings, cultural activities, or leisure pursuits as necessary.

CONCLUSION

Academic institutions must confront the challenges linked to work-life balance impacting their personnel and formulate a comprehensive strategy to design and execute initiatives that aid employees in managing their work-life balance, hence enhancing staff performance. Human Resource Management departments can assist educational institutions in fostering a stable institutional culture by supporting directors and managers, encouraging women in leadership positions, implementing new performance evaluation methods, and considering fairness and collegiality. The introduction of WLB programs can aid educational institutions and their representatives by fostering a robust work-family-life culture. Incorporating work-life balance frameworks into the annual planning of educational institutions undoubtedly enhances employee success. It is essential to instruct staff people to articulate their needs and desires, as they cannot anticipate management or the organisation to make decisions for them spontaneously

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Brand Equity Role on Consumers' Repurchase Intention of Fast Moving Consumer Goods

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ABSTRACT

The study intent to assess brand loyalty influence on buying intention and repurchase intention on Fast Moving Consumer Goods (FMCG) and results suggest that buying intention significantly influence consumer perceptions of quality and brand awareness, with repurchase intention being related to brand loyalty but not strongly. Consumer behavior does not significantly influence perceived quality, but brand awareness is positively influenced by buying intention. Price consciousness is positively influenced by consumer behavior, highlighting the complexities in the relationship between these factors.

KEYWORDS : *Buying intention, Brand awareness, Consumer perceptions.*

INTRODUCTION

Rawal, Agarwal, Choudhury and Pant (2024) Brand awareness is crucial factor for consumer choices in India's FMCG market. Word-of-mouth and personal recommendations impact brand awareness in rural areas, while digital marketing, social media presence, and advertising strategies influence it in urban areas. Thakur, Kathuria, and Kumari (2024) The study explores female consumers' perceptions of FMCG retail formats like Kirana stores, convenience stores, supermarkets, and online retailers, focusing on factors influencing engagement. Mohan, Ganesh, and Jayakrishnan (2024) The study explores factors influencing consumer preferences for foreign FMCG items, focusing on cultural considerations, cost considerations, social consequences, product specifications, self-related characteristics, and emotional determinants. Cultural identity is the most significant factor, while cost considerations do not significantly impact purchasing decisions. Mishra et al., (2024) The study examines consumer attitudes towards celebrity endorsements, revealing key factors influencing decision-making. Credibility and product quality perceptions significantly impact consumer perception. A strong positive correlation exists between celebrity endorsements and purchase intentions. Key determinants of sales include marketing expenditures, endorsement number, celebrity credibility, and product quality perception. Credible celebrities boost consumer trust and purchase likelihood. Verru (2024) study reveals that perception, attitude, and

living standards significantly influence consumers' intentions to buy FMGC products. The second model in the three-layer framework predicts consumer intent, suggesting specific factors within perception and attitude may be more critical. Pandey, Bajpai, and Tiwari (2023). The study suggest that female consumers' perceptions of FMCG retail formats like Kirana stores, supermarkets, and online retailers, focusing on factors like convenience, product variety, competitive pricing, customer service, and trust.

THEORETICAL BACKGROUND OF THE STUDY

Mishra and Farooqi (2024) The study found that affordability, awareness, and availability significantly influence green product purchase. The study reveals that affordability, awareness, and availability significantly influence green purchase behavior, while apprehension doesn't. It underscores the need for accessibility and information about green products' benefits. purchase behavior, while apprehension doesn't. It underscores the need for accessibility and information about green products' benefits. Kushwaha and Sharma (2024) The study reveals that functional, conditional, and epistemic values significantly influence fast-moving consumer goods purchase behavior, especially in green household cleaning products and social and emotional values have less influence.

Focusing on elements such credibility and impressions of product quality as main effects on consumer decision making

processes, the study offers a whole picture of consumer attitudes surrounding celebrity endorsements. Many facets of celebrity endorsements and consumer purchasing intentions showed clear positive relationships. Emphasizing their relevance in generating income for the business, it also found the major factors influencing sales include marketing expenses, quantity of endorsements, celebrity credibility and product quality perception.

Five elements were found by Kim (2008) that affect the development of brand equity by means of effective customer relationships: trust, customer satisfaction, relationship commitment, brand loyalty and brand awareness, so generating image and positive brand equity if one can properly manage their customer relationships. For internet firms, brand equity is directly created via brand loyalty and brand value associations (Rios & Riquelme, 2008). Although brands operate as high entrance barriers to new items, customers will pay a premium for the product and are unwilling to change to competitor products if brand loyalty is strong.

Saraswit, Dutta, and Saxena (2021). Kim (2008) found five elements that, in good customer interactions, shape the building of brand equity: trust, customer happiness, relationship commitment, brand loyalty, and brand awareness. Affecting brand equity directly and positively was the function of brand loyalty. Place, product, pricing, promotion, psychological and psychological elements and their effects also vary from one to another product; so, FMGC consumer behavior is mostly influenced by these elements.

They also emphasized the great significance of psychological elements in FMGC customer behavior. Based on their results, the present research addresses significant psychological issues like brand loyalty, brand awareness, perceived quality, brand association's and price consciousness and their relevance in FMGC industry.

Present research Found the research gap in socio economic role in FMGC goods too; Chatterjee et al. (2017) investigated the socio-economic components of FMCG to identify important variables that affect the purchasing intention of the customers.

DATA COLLECTION

Primary Data

The primary data were collected from 120 responses, but only 112 were used for analysis rest of them were defective. The information was collected through the schedule questionnaire method. The Questionnaire consists of two parts and the first part of questionnaire have 12 questions indented to gathering information for demographic variable and beliefs about their

buying preferences and the second part contains 42 questions designed for measuring behavior, repurchase and intention. All of them was design in the five-point Likert scale. For measuring perceived quality four items were used, in that first two from chen (2004) third and fourth item from Kim (2008). Simple random method was used to collect the sample units.

Table 1: Master Table

Demographic Variable		Number of Responses	Percentage
Gender	Male	45	40.2
	Female	67	59.8
Age	18-25	7	6.3
	25-35	23	20.5
	35-45	41	36.6
	45-55	34	30.4
	55 and above	7	6.3
Educational Qualification	Diploma	13	11.6
	Higher secondary Schooling	23	20.5
	Graduates	52	46.4
	Postgraduates	12	10.7
	Professional degree and other	12	10.7
Monthly Income (in Rupees)	< 10000	27	24.1
	10000 – 20000	37	33.0
	20000 – 30000	21	18.8
	30000 – 40000	15	13.4
	40000 – above	12	10.7
Marital Status	Married	84	75.0
	Unmarried	28	25.0

Source : primary data

RESULT AND DISCUSSION

Results of one-way ANOVA with Scheffe's Post – hoc

The descriptive statistics show that consumers' buying intention towards online shopping is good and above average mean score (2.50) of the five-point scale. In this study, consumer Age (H1), education (H2) and income (H3) effect on FMGC Consumer buying intention. The result is illustrated in the below table (ANOVA with Post Hoc test). Statistical analysis and results (buying intent and demographic variables) One-way ANOVA explains to us if there is any significant difference in the mean scores of the dependent variable across the groups and if it is different,

Post- hoc tests were done to find out where these differences lies (Pallant, 2007). The present study consists of the unequal sample (group in size), so the researcher goes with Tukey Post – hoc tests, which most suitable unequal groups.

Table 2: Dependent Variable: Buying intention

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
H1 Age	14.576	4	3.644	3.195	.014
H2 Education	1.968	3	.656	.557	.644
H3 Income	4.224	4	1.056	.899	.465

Source: Primary Data

In this group analysis, the researcher first considers online buying intention as the dependent variable while the Age, education, and income as the independent variables. Below the table shown H 1, H 2, and H 3 results. Accepted @5% significant, H 2 and H 3 indicate that, in terms of online shopping intention, education and income of the several groups of respondents have no appreciable difference. Sign value education and income are .644 and .465 respectively, much above the necessary $p > 0.05$ norms. Age caused the sign value (.014) below the necessary $P > 0.05$ to be rejected. The study reveals that the 18–25 age range differs notably from other consumer groups based on Tukey's Post-hoc testing with multi-group comparison. (View the annexure).

Descriptive Statistic of Hypothesis Variables

The present research is based on brand equity determinant's role in buying intention, consume behavior and repurchase intention of the FMGC consumer. The present research hypotheses to test the brand equity determinants and price consciousness role in buying intention, consume behavior and repurchase intention with that the research can easily various determination's role in FMGC market. FMCG's brand equity Results revealed that four elements define consumer-based brand equity for FMCG: brand association, brand loyalty, perceived quality and brand awareness. By far the most important source of brand equity was brand association; brand awareness had the least impact.

Table 3: Descriptive Statistic of Hypothesized Variables

Study variables	No items	Mean	Std. Deviation
brand loyalty	4	3.73	0.81
perceived quality	4	3.85	0.94
brand awareness	4	3.45	0.87

Price consciousness	4	3.39	0.826
Repurchase intention	3	3.61	0.96
Consumer behavior	3	3.26	0.801
	5	4.05	0.99

Source: Primary Data

Interpretation

The buying intention has a higher mean score (4.05) compared to customer behavior (3.26). The perceived quality (3.85) and price consciousness (3.39) stands respectively indicating how integral for the customers. Along these, the standard deviation of brand loyalty (0.81) is slightly lower than the brand awareness (0.87)

MEASURED STRUCTURAL EQUATION MODEL (MSEM)

The hypotheses test in MSEM, based on three endogenous (buying intention, buyer behavior and repurchase intention) and seven exogenous brand loyalty, perceived quality, brand awareness, price consciousness, repurchase intention, consumer behavior and buying intention.

H1 Brand loyalty has a significant positive effect on buying intention of toothpaste.

H2 Toothpaste consumer behavior is significant positive by Brand loyalty

H3 Brand loyalty has a significant positive effect on consumer's toothpaste repurchase intention perceived quality

H4 Perceived quality has a significant positive effect on buying intention of toothpaste.

H5 Toothpaste consumer behavior is significant positive by Perceived quality

H6 Perceived quality has a significant positive effect on consumer's toothpaste repurchase intention.

H7 Brand awareness and association has a significant positive effect on buying intention of toothpaste.

H8 Toothpaste consumer behavior is significant positive by brand awareness and association

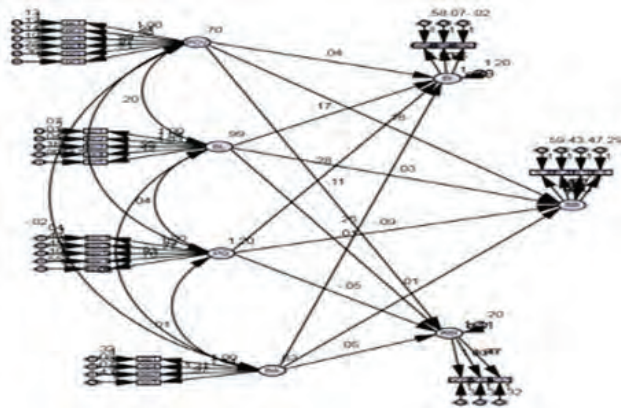
H9 Brand awareness and association has a significant positive effect on consumer's toothpaste repurchase intention.

H10 Price consciousness has a significant positive effect on buying intention of toothpaste.

H11 Toothpaste consumer behavior is significant positive by Price consciousness

H12 Price consciousness has a significant positive effect on consumer's toothpaste repurchase intention.

MEASURED STRUCTURAL EQUATION MODEL (for toothpaste consumer behavior) The hypotheses test in MSEM and SEM, based on one endogenous (buying intention) and seven exogenous (i) Brand loyalty ii) Perceived quality iii) Brand awareness iv) Price consciousness v) Repurchase intention vi) Consumer behavior vii) Buying intention).



	Exogenous variable	Endogenous variable	Estimate	S.E.	C.R.	P	Results
H 1	Buying intention	< Brand loyalty	.166	.065	2.560	.010	Accepted
H 2	Consumer behavior	< Brand loyalty	.030	.056	.539	.590	Rejected
H 3	Repurchase intention	< Brand loyalty	.005	.035	.156	.876	Rejected
H 4	Buying intention	< Perceived quality	.282	.058	4.847	***	Accepted
H 5	Consumer behavior	< Perceived quality	-.091	.050	-1.813	.070	Rejected
H 6	Repurchase intention	< Perceived quality	-.051	.032	-1.592	.111	Rejected
H 7	Buying intention	< Brand awareness	.256	.081	3.160	.002	Accepted
H 8	Consumer behavior	< Brand awareness	.010	.069	.145	.885	Rejected
H 9	Repurchase intention	< Brand awareness	.054	.044	1.211	.226	Rejected
H 10	Buying intention	< Price consciousness	.044	.079	.556	.578	Rejected
H 11	Consumer behavior	< Price consciousness	.162	.069	2.363	.018	Accepted
H 12	Repurchase intention	< Price consciousness	.106	.045	2.341	.019	Accepted

The majority of consumers are interested in FMCG, and it shows in the buying intent mean score (4.05) it above means score of the study (2.5). While considering consumer behavior, brand awareness and brand loyalty (0.801, 0.87, 0.81) having low standard deviation and imply they have a similar perception towards FMCG.

H1 is accepted, brand loyalty is significant influences buying intention and path is positive, and its influence is estimated at 0.166 @ p-value of 0.010. An estimated 0.166 is a considerable impacting level in this study. H2 is rejected, consumer behavior positively influences brand loyalty but not significant. It suggests that consumer behavior does not influence the brand loyalty of the consumers. H3 is rejected, repurchase intention positively influences brand loyalty but, not at a significant level. It suggests that the repurchase intention to buy the products is not comparatively low.

H4 is accepted, buying intention positively influences perceived quality and the path is positive. The perceived quality has a significant impact on buying intention as it makes the consumer's incline towards the products. H5 is rejected, consumer behavior does not influence perceived quality of the FMCG products. And its influence is estimated at -0.91 @ p-value of 0.70. An estimated -0.91 is a considerable impacting level in this study. H6 is rejected, repurchase intention does not influence perceived quality of the products. And, its influence is estimated at -0.51 @ p-value of 0.111. The repurchase intention has a significant impact on perceived quality as it makes the consumer's incline towards the products. H7 is accepted, buying intention influences brand awareness of the products. And, its influence is estimated at 0.256 @ p-value of 0.002. The brand awareness has a significant impact on the buying of the products. This enables us to understand the view of consumers. H8 is rejected, consumer behavior negatively influences brand awareness of the FMCG products. And, its influence is estimated at 0.010 @ p-value of 0.885. This enables us to understand that despite the indifferences.

H9 is rejected, consumer behavior negatively influences brand awareness on the value of the FMCG product. And, its influence is estimated at 0.044 @ p-value of 0.578m consumer behavior is minimum and yet considerable.

H10 is rejected, buying intention negatively influences price consciousness on the concept of buying intention. And, its influence is estimated at 0.044 @ p-value of 0.578. The buying intention of the product is still in at a bay as there is a very slight change to it.

H11 is accepted, consumer behavior positively and significantly influences price consciousness of the products FMCG. And, its influence is estimated at 0.162 @ p-value of 0.018.

H12 is accepted, repurchase intention influences price consciousness significantly on the products on FMCG. And, its influence is estimated at 0.106@ p0value of 0.019, The research proves the price consciousness of the product still plays a hue role on their aspect.

MANAGERIAL IMPLICATIONS

Repurchase intention is related to brand loyalty but does not have a significant impact, suggesting consumers may not feel strongly about repurchasing specific brands. Perceived quality is positively influenced by buying intention, indicating that consumers perceive higher quality in products. However, consumer behavior does not significantly influence perceived quality, suggesting that consumers may not correlate their behaviors with perceptions of quality. Brand awareness is positively influenced by buying intention, with a significant impact estimated at 0.256. Price consciousness is positively influenced by consumer behavior, with a significant impact on repurchase intention. Overall, the study highlights the importance of brand loyalty and buying intention in shaping consumer perceptions of quality and brand awareness, while revealing complexities in the relationships between consumer behavior and these factors.

CONCLUSION

The study explores consumer attitudes and behaviors towards fast-moving consumer goods (FMCG) products. It reveals that buying intent is significantly higher than the average score, indicating strong consumer interest in FMCG. Brand loyalty significantly influences buying intention, with a positive path estimated at 0.166. However, consumer behavior does not significantly influence brand loyalty, suggesting other factors may be more impactful.

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Exploring the Relationship Between AI Personalization Usage and User Satisfaction: A Statistical Analysis

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ABSTRACT

AI-driven personalization has become an integral component of digital experiences, tailoring content, recommendations, and advertisements to user preferences. However, the extent to which AI personalization usage impacts user satisfaction remains an open question. This study aims to explore the relationship between AI personalization usage frequency and user satisfaction, analyzing whether increased exposure to AI-driven recommendations leads to higher satisfaction levels. A quantitative research approach was adopted, utilizing a crosstabulation analysis and the Chi-Square test to examine user responses from a sample of 500 participants. The study evaluated five categories of AI personalization usage—Always, Often, Sometimes, Rarely, and Never—against different levels of satisfaction with AI personalization. The results indicate no statistically significant relationship between AI personalization usage and satisfaction ($p=0.490$), suggesting that frequent interaction with AI-driven recommendations does not necessarily translate into higher satisfaction levels. The findings challenge the assumption that greater AI personalization leads to improved user experience and highlight the need to consider other influencing factors, such as trust in AI systems, recommendation relevance, and privacy concerns. Additionally, the study underscores the importance of understanding user expectations and preferences when designing AI-driven personalization strategies. This research contributes to the growing discourse on AI-driven personalization and consumer behavior, offering insights for businesses, AI developers, and policymakers. Future studies should incorporate qualitative aspects of AI personalization experiences, user trust dynamics, and the long-term impact of AI recommendations to gain a more comprehensive understanding of user satisfaction.

KEYWORDS : *AI personalization, User satisfaction, AI-driven recommendations, Consumer behavior, Statistical analysis, Privacy concerns, Trust in AI.*

INTRODUCTION

The rapid advancement of artificial intelligence (AI) has revolutionized digital experiences by enabling personalized recommendations, tailored content, and automated decision-making across various domains, including e-commerce, entertainment, social media, and healthcare [1] [2]. AI-driven personalization is designed to enhance user engagement by analyzing behavioral patterns, preferences, and past interactions to deliver customized suggestions. While AI personalization is widely adopted by businesses to improve customer satisfaction and retention, its actual impact on user satisfaction remains a subject of debate. Some users find AI-driven recommendations highly beneficial, leading to enhanced experiences and convenience,

whereas others may feel indifferent or even dissatisfied due to issues such as algorithmic bias, irrelevant suggestions, or privacy concerns [3] [4].

The increasing reliance on AI personalization has sparked discussions on whether frequent exposure to AI-driven recommendations enhances user satisfaction. AI algorithms are designed to improve over time by learning user preferences, but this does not always translate into positive user experiences. Some users appreciate the convenience and accuracy of personalized recommendations, while others may feel overwhelmed, manipulated, or concerned about data privacy [5]. Additionally, users who frequently interact with AI personalization might develop algorithmic fatigue, where repeated suggestions reduce novelty and engagement.

Given these conflicting perspectives, it becomes essential to investigate whether the frequency of AI personalization usage correlates with user satisfaction

RESEARCH DESIGN

The research follows a quantitative, descriptive, and analytical research design to examine the impact of AI-driven personalization on customer experience in online retail. The study employs survey-based data collection and statistical analysis to investigate demographic factors, customer behavior, and AI usage in e-commerce.

Nature and Source of Data

- Nature of Data: The data collected is quantitative as it involves structured responses in the form of multiple-choice questions from a questionnaire.
- Source of Data: The study uses both primary and secondary data sources to support the research objectives

Primary Data

- Definition: Primary data refers to first-hand information collected directly from respondents.
- Method of Collection: The study uses a structured questionnaire with 30 questions related to demographics, AI personalization usage, and customer experience in online retail.
- Data Collection Tool: Online survey forms (Google Forms) distributed via email and social media.
- Sample Size: 500 respondents.
- Respondents: Online retail consumers who engage in e-commerce shopping and interact with AI-driven recommendations.

Secondary Data

- Definition: Secondary data refers to information obtained from pre-existing sources.
- Sources Used:
 - o Research papers, articles, and reports related to AI in e-commerce, customer experience, and digital marketing.
 - o Market reports and white papers from consulting firms, industry leaders, and AI technology providers.
 - o Data from government or business research organizations (e.g., Statista, McKinsey, Gartner).

Population Design

Target Population: Online shoppers who interact with AI-driven personalized recommendations in e-commerce platforms.

Sampling Frame: Individuals from diverse age groups, education levels, and occupations who shop online.

Sampling Technique

Stratified Random Sampling – ensures representation across different age groups, gender, occupation, and online shopping frequency.

Convenience Sampling – used for online survey distribution to reach respondents efficiently.

DATA ANALYSIS AND INTERPRETATION

Users who frequently use AI personalization have higher satisfaction levels

Null Hypothesis: Frequency of AI personalization usage does not significantly affect satisfaction levels.

Alternative Hypothesis: Users who frequently use AI personalization have significantly higher satisfaction levels.

Table 1 depicts the Contingency table for the association between the Usage of AI Personalization and Overall Satisfaction with AI Personalization. Figure 1 presents the graphical representation of the association between the Usage of AI Personalization and Overall Satisfaction with AI Personalization.

Table 1: Contingency table for the association between the Usage of AI Personalization and Overall Satisfaction with AI Personalization

Usage of AI Personalization * Overall Satisfaction with AI Personalization Crosstabulation

		Overall Satisfaction with AI Personalization					Total
		Dissatisfied	Neutral	Satisfied	Dissatisfied	Very Satisfied	
Usage of AI Personalization	Always	21	31	19	13	20	104
	Never	25	19	13	23	18	98
	Often	18	18	18	20	16	90
	Rarely	24	29	31	18	26	128
	Sometimes	15	23	12	16	14	80
Total		103	120	93	90	94	500

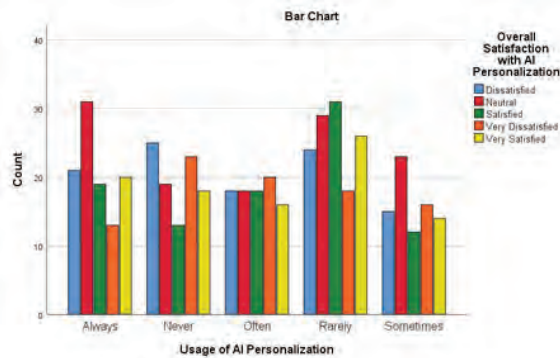


Fig. 1: Graphical representation of the association between the Usage of AI Personalization and Overall Satisfaction with AI Personalization

From the table 1 and figure 1, presents the relationship between the Usage of AI Personalization and Overall Satisfaction with AI Personalization based on survey responses. The key observations from the data include:

Variability Across Usage Categories

- Among those who always use AI personalization, satisfaction levels are somewhat evenly distributed, with 31 respondents remaining neutral, 21 dissatisfied, and 20 very satisfied.
- Those who never use AI personalization have a slightly higher count of dissatisfaction (25 dissatisfied, 23 very dissatisfied).
- The “rarely” category has the highest number of respondents (128) and the largest count of satisfied users (31).
- The “sometimes” category has fewer respondents (80) and shows a lower overall satisfaction trend compared to other groups.

Satisfaction Trends

- Satisfaction does not show a strong increasing or decreasing trend based on AI personalization usage.
- All usage categories have a mix of satisfied, neutral, and dissatisfied respondents, indicating that frequent AI personalization does not necessarily lead to higher satisfaction.

Table 2 depicts the chi-square test for the association between the usage of AI personalization and overall satisfaction with AI personalization.

Table 2: Chi-Square test for the association between the Usage of AI Personalization and Overall Satisfaction with AI Personalization Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	15.472 ^a	16	.490
Likelihood Ratio	15.454	16	.492
N of Valid Cases	500		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 14.40.

From the table 2, The Pearson Chi-Square value is 15.472 with 16 degrees of freedom, and the p-value is 0.490. Since the p-value is greater than 0.05, we fail to reject the null hypothesis. This indicates that there is no statistically significant relationship between the Usage of AI Personalization and Overall Satisfaction with AI Personalization at the 5% significance level.

Users who frequently use AI personalization have higher satisfaction levels

Null Hypothesis: There is no significant relationship between daily AI personalization usage and comfort with data sharing.

Alternative Hypothesis: People who use AI personalization daily are significantly more comfortable sharing their data.

Table 3 depicts the association between the daily AI personalization usage and comfort with data sharing. Figure 2 presents the graphical representation of the association between the daily AI personalization usage and comfort with data sharing.

Table 3: Contingency table for the association between the daily AI personalization usage and comfort with data sharing

Usage of AI Personalization * comfortable sharing your data for AI-driven personalization Crosstabulation							
		comfortable sharing your data for AI-driven personalization					Total
		Dissatisfied	Neutral	Very Satisfied		Total	
				Dissatisfied	Very Satisfied		
Usage of AI Personalization	Always	15	26	21	20	22	104
	Never	22	19	19	15	23	98
	Often	14	21	17	19	19	90
	Rarely	22	24	29	23	30	128
	Sometimes	20	17	12	17	14	80
Total		93	107	98	94	108	500

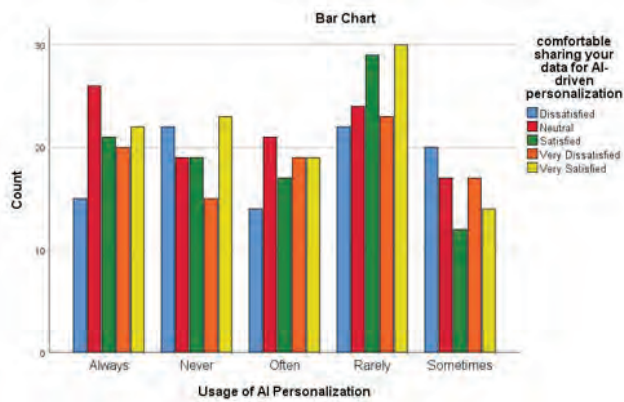


Fig. 2: Graphical representation of the association between the daily AI personalization usage and comfort with data sharing

From the table 3 and figure 2, examines the relationship between Usage of AI Personalization and Comfort Level in Sharing Data for AI-Driven Personalization.

No Strong Preference for Sharing Data Across Usage Categories:

- Among those who always use AI personalization, responses are fairly distributed across all satisfaction levels, with 26 respondents being neutral, 22 very satisfied, and 20 very dissatisfied.
- Those who never use AI personalization also show a mixed response, with 22 dissatisfied and 23 very satisfied, indicating no strong trend.
- The “rarely” category (highest respondent count of 128) has more satisfied (29) and very satisfied (30) respondents, suggesting that even occasional users may be comfortable sharing their data.
- The “sometimes” category has relatively fewer satisfied respondents compared to other groups.

No Clear Trend Between Usage and Comfort Level:

- Respondents who use AI personalization frequently (always, often) do not show significantly higher comfort in sharing data.
- Dissatisfaction and satisfaction appear evenly distributed across all categories.

Table 4 depicts the chi-square test for the association between the daily AI personalization usage and comfort with data sharing.

Table 4: Chi-Square Test for the association between the daily AI personalization usage and comfort with data sharing Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	9.220a	16	.904
Likelihood Ratio	9.204	16	.905
N of Valid Cases	500		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 14.88.

From the table 4, The Pearson Chi-Square value is 9.220 with 16 degrees of freedom, and the p-value is 0.904. Since the p-value is much greater than 0.05, we fail to reject the null hypothesis. This suggests that there is no statistically significant relationship between Usage of AI Personalization and Comfort Level in Sharing Data at the 5% significance level.

Higher AI personalization awareness leads to greater satisfaction with AI-driven recommendations

Null Hypothesis: Awareness of AI personalization does not significantly affect satisfaction with AI-driven recommendations.

Alternative Hypothesis: Higher awareness of AI personalization leads to significantly greater satisfaction with AI-driven recommendations.

Table 5 depicts the Contingency table for the association between the Awareness of AI personalization and satisfaction with AI-driven recommendations. Figure 3 presents the graphical representation of the association between the Awareness of AI personalization and satisfaction with AI-driven recommendations.

Table 5: Contingency table for the association between the Awareness of AI personalization and satisfaction with AI driven recommendation

Awareness of AI Personalization * Overall Satisfaction with AI Personalization Crosstabulation

		Overall Satisfaction with AI				
		Dissatisfied	Neutral	Satisfied	Very Satisfied	Total
Awareness of AI Personalization	No	49	61	40	42	233
	Yes	54	59	53	48	267
Total		103	120	93	90	500

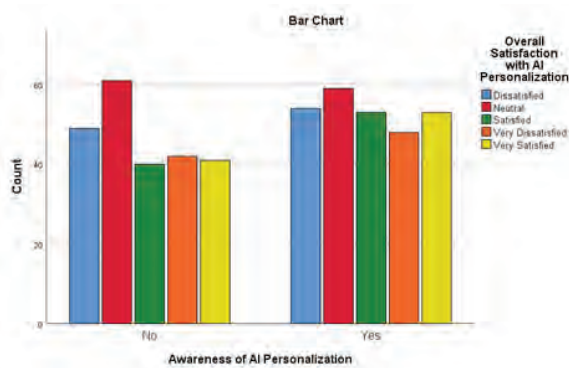


Fig. 3: Graphical representation of the association between the Awareness of AI personalization and satisfaction with AI driven recommendation

From the table 5 and figure 3, explores the relationship between Awareness of AI Personalization and Overall Satisfaction with AI Personalization.

- Satisfaction Levels are Similar Across Awareness Groups:
- Among those who are not aware of AI personalization (233 respondents), 61 are neutral, while 49 are dissatisfied and 41 are very satisfied.
- Among those who are aware (267 respondents), satisfaction levels are similarly distributed, with 59 neutral, 54 dissatisfied, and 53 very satisfied.
- Both groups have a relatively even spread of responses, indicating that awareness does not strongly influence satisfaction.

No Clear Trend Between Awareness and Satisfaction

- The number of satisfied users is slightly higher among those who are aware (53 vs. 40), but the difference is not substantial.
- The proportions of dissatisfied and very dissatisfied users are quite similar in both groups.

Table 6 gives the Chi-Square test for the association between the Awareness of AI personalization and satisfaction with AI driven recommendation.

Table 6: Chi-Square test for the association between the Awareness of AI personalization and satisfaction with AI driven recommendation Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	1.721a	4	.787

Likelihood Ratio	1.722	4	.787
N of Valid Cases	500		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 41.94.

From the table 6, The Pearson Chi-Square value is 1.721 with 4 degrees of freedom, and the p-value is 0.787. Since the p-value is much greater than 0.05, we fail to reject the null hypothesis. This suggests that there is no statistically significant relationship between Awareness of AI Personalization and Overall Satisfaction with AI Personalization at the 5% significance level.

Individuals dissatisfied with AI personalization are more likely to perceive it as a privacy threat

Null Hypothesis: Satisfaction with AI personalization is not significantly associated with perceiving it as a privacy threat.

Alternative Hypothesis: Individuals dissatisfied with AI personalization are significantly more likely to perceive it as a privacy threat.

Table 7 depicts the contingency table for the association between the Overall Satisfaction with AI Personalization and AI personalization compromises your privacy. Figure 4 presents the graphical representation of the association between the Overall Satisfaction with AI Personalization and AI personalization compromises your privacy.

Table 7: Contingency table for the association between the Overall Satisfaction with AI Personalization and AI personalization compromises your privacy

		Overall Satisfaction with AI Personalization * AI personalization compromises your privacy Crosstabulation					
		AI personalization compromises your privacy					
Overall Satisfaction with AI Personalization	Dissatisfied	Dissatisfied	Neutral	Satisfied	Dissatisfied	Very Satisfied	Total
	Neutral	24	23	23	16	17	103
	Satisfied	22	23	20	26	29	120
	Very Dissatisfied	22	13	16	27	15	93
	Very Satisfied	17	24	14	19	16	90
Total		109	101	91	106	93	500

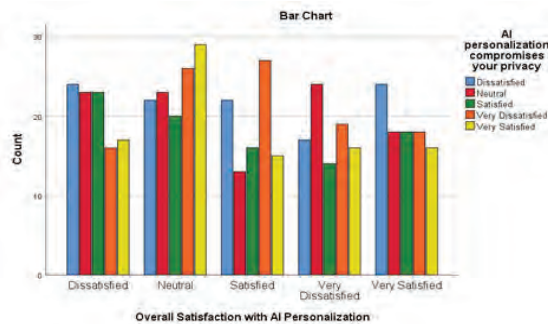


Fig. 4: Graphical representation of the association between the Overall Satisfaction with AI Personalization and AI personalization compromises your privacy

From the table 7 and figure 4, examines the relationship between Overall Satisfaction with AI Personalization and Perception of AI Personalization Compromising Privacy.

No Clear Trend Between Satisfaction and Privacy Concerns

- Among dissatisfied users, responses are fairly distributed, with 24 believing AI compromises privacy, 23 being neutral, and 17 strongly agreeing that it does not.
- Neutral users also have a spread of opinions, with 22 believing AI compromises privacy and 29 strongly disagreeing.
- Even satisfied users do not show a clear inclination towards either privacy concerns or comfort.
- Very satisfied users also have mixed opinions, with 24 believing AI compromises privacy, but 18 being neutral and 16 strongly disagreeing.

Diverse Views on Privacy Across All Satisfaction Levels

- Across all satisfaction levels, concerns about privacy are not significantly higher or lower in any specific group.
- The data does not indicate that higher satisfaction leads to reduced privacy concerns or vice versa.

Table 8 gives the Chi-Square test for the association between the Overall Satisfaction with AI Personalization and AI personalization compromises your privacy.

Table 8: Chi-Square test for the association between the Overall Satisfaction with AI Personalization and AI personalization compromises your privacy Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	14.576a	16	.556

Likelihood Ratio	14.331	16	.574
N of Valid Cases	500		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 16.38.

From the table 8, The Pearson Chi-Square value is 14.576 with 16 degrees of freedom, and the p-value is 0.556. Since the p-value is much greater than 0.05, we fail to reject the null hypothesis. This suggests that there is no statistically significant relationship between Overall Satisfaction with AI Personalization and Perception of AI Personalization Compromising Privacy at the 5% significance level.

CONCLUSION

The results suggest that there are no statistically significant relationships between AI personalization usage, awareness, satisfaction, privacy concerns, data-sharing comfort, and purchase influence. This indicates that:

- AI personalization does not universally influence users' perceptions or behavior, and satisfaction levels vary independently of AI usage frequency.
- Privacy concerns remain prevalent across all satisfaction levels, implying that satisfaction with AI personalization does not necessarily mean users feel secure.
- Users across different age groups exhibit diverse responses to AI-driven purchase recommendations, suggesting other factors such as individual preferences, trust in AI, or prior experiences with AI-driven personalization may play a larger role.

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Analysis of Faculty Perceptions on Career Development Programs and Training in Higher Education Institutions in Thanjavur

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ABSTRACT

Career development programs and training are essential in all areas of professional life. They provide new skills and knowledge and help people attain higher status. Educational institutions face tough competition among them and have strategies to boost their names among the crowd. They are committed to providing good and quality education to society. Providing quality education includes various factors. One of the most important factors is the quality of the faculty.

All the educational institutions are taking various measures and activities to enrich the knowledge of the faculties. The National Assessment and Accreditation Council (NAAC) in India lays down certain procedures and standards for the quality of faculties and improves the quality by organising professional development programs. Therefore, educational institutions are taking measures to look after the quality of faculties and organise career development programs and training.

The researcher investigates faculty perceptions of career development programs and training and attempts to discover the effects. In this study, a descriptive research design with a mixed methods approach is used, incorporating both qualitative and quantitative techniques. This study targets faculty members working in higher education institutions in Thanjavur, Tamil Nadu, India, and employs simple random sampling with a sample size of 165 respondents from this population. Primary data were collected using a structured questionnaire and the analysis was performed through a descriptive statistical methods.

This study finds that there is an association between the experience of the respondents and the frequency of their participation in career development programs and training. Higher education institutions can invest to align faculties for their career advancement. Educational stakeholders can foster a positive supportive environment for faculties by executing the recommendations provided in the study, which in turn enhances their quality.

KEYWORDS : Faculty perceptions, Career development programs and training, Higher education institutions.

INTRODUCTION

In today's world, countless educational institutions are springing up to keep up with the increasing population. They face tough competition among themselves and have strategies to boost their names among the crowd. These institutions are committed to providing good and quality education to society. Providing quality education includes various factors. One of the most important factors is the quality of the faculty. All the educational institutions are taking various measures and activities to enrich the knowledge of the faculties. The National Assessment and Accreditation Council (NAAC) in India lays down certain procedures and

standards for the quality of faculties and improve quality by organising professional development programs. Therefore, all educational institutions look after the quality of faculties. They have organised many professional development programs and training for the development of faculties. This article analyses the importance of career development program and training in the present scenarios.

CONCEPTUAL FRAMEWORK

Career Development Programs and Training is a planned approach designed to supports individuals navigate career challenges. This approach encompasses various activities

including symposiums, guest lectures, seminars, conferences, faculty development programs, workshops, webinars, professional development programs as well as soft skill training. These opportunities are organised with a specific design and action plan to keep participants informed about current trends in their respective fields.

These offerings are designed with clear objectives and well-defined targets to ensure focused and impactful outcomes. The programs emphasize exploring unknown areas within a sector. Distinguished speakers comprising esteemed academicians, scientists, industrialists, dynamic entrepreneurs, and experienced trainers are invited to share their expertise and insights. Their contributions significantly enhance participants' knowledge, skills in their fields of study. These initiatives align the faculty members' career goals with institutional objectives, ultimately fostering professional growth and development.

STATEMENT OF THE PROBLEM

The future of a country depends significantly on its youth. The younger generation relies on their faculty for guidance, knowledge and mentorship, which are essential for their holistic development. Faculty members play a major role in nurturing the younger generation by providing the necessary tools and resources to help them navigate their studies and prepare for their future careers. Their expertise and support are vital for helping students build the confidence and skills needed to succeed in life. Hence, empowering the faculty is essential for the national development. In response to this need, educational institutions are taking steps to enhance the skills of their faculty through career development programs and training initiatives.

This research aims to assess the significance of these programs and examine whether they genuinely benefit faculty members or if they instead contribute to their workload. Therefore, it is increasingly important to analyse faculty perceptions of career development programs and training.

OBJECTIVES

- To assess the level of faculty's awareness of available career development opportunities
- To evaluate the effectiveness of the programs and training from the faculty's perspective
- To explore the factors that hinder faculty participation
- To scrutinise the expectations and preferences of faculty members

RESEARCH METHODOLOGY

This study utilises a descriptive research design with a mixed methods approach, incorporating both qualitative and quantitative techniques. It focuses on faculty members working in higher education institutions in Thanjavur, Tamil Nadu, India. A simple random sampling method was used to select a sample size of 165 respondents from this population. Primary data was collected using a structured questionnaire and the analysis was conducted through descriptive statistical methods.

Hypothesis

There is no significant influence of demographic variables on participation in career development programs and training.

Table 1: Demographic Profile of the Respondents

Particulars	Classification	No. of Respondents	Percentage
Gender	Male	93	56
	Female	72	44
Age	21-30	51	31
	31-40	45	27
	41-50	57	35
	above 50	12	7
Marital Status	Single	68	41
	Married	97	59
Education	Post Graduate, (Pursuing Ph.D., SET/ NET)	44	27
	Post Graduate, M.Phil., (Pursuing Ph.D., SET/ NET)	59	36
	Doctorates, (SET/NET)	62	38
Designation Education	Assistant Professor	131	79
	Associate Professor	28	17
	Professor	6	4
Experience	Below 2 yrs.	17	10
	2 to 5 yrs.	36	22
	5 to 8 yrs.	38	23
	8 to 12 yrs.	35	21
	Above 12 yrs.	39	24
Monthly Income	Below 25,000	73	44

Monthly Income	25,000 to 50,000	62	38
	50,000 to 1,00,000	24	15
	Above 1,00,000	6	4

The above table provides a clear overview of the demographic profile of the 165 respondents. Among them, 56% are male, while the remaining percentages are female. In terms of age, 35% of the respondents fall within the 41 to 50 year old category. Additionally, 59% of the respondents are married. Regarding educational qualifications, 38% hold a doctorate. The majority, 79% hold the designation of Assistant professor. Furthermore, 24% of the respondents have over 12 years of experience. Lastly, 44% of the respondents earn a monthly income of less than 25,000.

Opinion for the following statements related to Career Development Programme & Training

Particulars	Classification	No. of Respondents	Percentage
How often you participates the career development program in a year?	1 to 3	37	22
	4 to 7	66	40
	8 to 10	34	21
	above 10	28	17
Did you permit to avail OD for attending the career development program?	On Duty	64	39
	Casual Leave	79	48
	Loss of Pay	21	13
Where did you get the information about the training programs?	Institutions	63	38
	Colleagues	59	36
	Web sites	43	26

Source: Primary data

The respondents were asked general questions regarding their participation in career development program over the course of a year, 40% of the respondents participate 4 to 7 programs annually, and more than 48% took casual leave to attend these programs. 38% of the respondents received information about the training program from their institutions.

Statement	Strongly Agree		Agree		Neutral		Disagree		Strongly Disagree	
	N	%	N	%	N	%	N	%	N	%
Awareness										
Do you believe Career Development Programs and Training are necessary for faculty professional growth?	72	44	60	36	15	9	10	6	8	5
Are you funded for the training based on the significance of need?	29	18	36	22	25	15	43	26	32	19
It supports the growth of the skills necessary for my career.	51	31	87	53	11	7	9	5	7	4
It aids to deepen my understanding of the new region	46	28	94	57	9	5	7	4	9	5
It boosts my confidence and self-esteem	51	31	77	47	12	7	14	8	11	7
Effectiveness										
My participation in the program is voluntary	17	10	51	31	25	15	53	32	20	12
It assists in setting up time bound and plans	69	42	61	37	15	9	11	7	9	5
It guides in taking correct and timely action to overcome obstacles	65	39	67	41	17	10	13	8	3	2
It access to learning resources and materials	66	40	87	53	3	2	5	3	4	2
It assists recalling and applying the learned information in day-to day life	68	41	72	44	9	5	10	6	6	4
It paves way to strengthen my profile	59	36	84	51	11	7	6	4	5	3
It encourage to foster positive attitude and support colleagues and students	61	37	81	49	13	8	6	4	4	2
Helps to understand the organization culture, mission and values	42	25	74	45	18	11	18	11	13	8

Trains in conflict resolution and improve smooth relationship	48	29	81	49	14	8	13	8	9	5
Turnover ratio is reduced	44	27	76	46	16	10	15	9	14	8
Is participation in programs and training one of the criteria for getting increments and promotions?	58	35	84	51	9	5	8	5	6	4
Hindrances										
Do you feel that your income level is insufficient compared to your expected expenses for registration, conveyance and other costs related to such programs and training?	70	42	65	39	6	4	15	9	9	5
Did your institution restrict you, from availing on-duty facilities to participate in such programs and trainings?	68	41	68	41	11	7	13	8	5	3
Did you struggle to alter your classes in order to participate in the programs and trainings?	57	35	86	52	7	4	8	5	7	4
Did you find it difficult to travel a long distance to reach the venue for the programs?	30	18	39	24	25	15	55	33	16	10
Did you find it difficult to participate in the programs and training due to tight schedule and work pressure?	71	43	74	45	7	4	9	5	4	2
Did you experience any technical issues, such as internet connection problems, projector malfunctions, presentation faults or sound system issues, during the sessions?	43	26	67	41	15	9	23	14	17	10
Expectation and preferences										
Do you think Career Development Programs and Training are important for faculty advancement?	67	41	73	44	10	6	10	6	5	3
My institution organizes many Career Development Programs and Training sessions	46	28	51	31	24	15	23	14	21	13
My career objectives can be achieved through the programs and training	62	38	69	42	11	7	14	8	9	5
Does the relevance of the program's topic influence your decision to participate?	64	39	68	41	13	8	12	7	8	5
Does the content of the session influence your decision to participate?	66	40	87	53	3	2	5	3	4	2
Does the knowledge and familiarity of the program's resource persons influence your decision to participate?	42	25	74	45	18	11	18	11	13	8
Does the reliability of the organising institution influence your decision to participate?	72	44	74	45	6	4	9	5	4	2
Does the validity of the program's certification influence your decision to participate?	68	41	72	44	9	5	10	6	6	4
Does the time duration of the program influence your decision to participate?	52	32	65	39	21	13	15	9	12	7
Does the cost-benefit of the program's registration fees influence your decision to participate?	63	38	78	47	12	7	7	4	5	3

Does the hands-on training in the program influence your decision to participate?	44	27	76	46	16	10	15	9	14	8
Do future benefits, such as highly paid jobs, influence your decision to participate?	49	30	79	48	14	8	10	6	13	8

Source: Primary data

This table presents the awareness, effectiveness, hindrances, and perceptions of faculty members regarding career development programs and training. The respondents were asked about their reasons for participating in these programs. The majority of respondents 44% strongly agreed and 36% agreed that they have upgraded their knowledge and skills through the programs and training.

Additionally, 44% reported that they have retained the knowledge and skills acquired from these experiences. In total 40% of the respondents agreed or strongly agreed that their institutions financially supported them participating in the programs and training. Furthermore, 53% of the respondents stated that the programs help improve their skills. While 57% agreed that training provides a deeper understanding in new fields. Also, 47% of respondents felt that the training boosts their confidence and self-esteem. Another 57% indicated that they participated in the programs to enhance their knowledge and skills.

The following activities were organized to upgrade, reinforce and enhance knowledge and skills in higher education institutions: guest lectures, workshops, seminars, symposiums, faculty development programs, conferences, professional training sessions, webinars, group discussions, e-learning, mentoring or coaching, hands-on training, role-playing, case studies and other related programs.

DATA ANALYSIS AND INTERPRETATION

CHI-SQUARE TEST

To test the association between the experience and the number of (frequency) participation in the career development program in a year.

Observed Frequency (O)

Experience / Frequency of Participation	Below 2 yrs.	2 to 5 yrs.	5 to 8 yrs.	8 to 12 yrs.	Above 12 yrs.	Total
1 to 3	7	15	8	7	0	37
4 to 7	8	13	14	16	15	66
8 to 10	2	8	8	7	9	34
above 10	0	0	8	5	15	28
Total	17	36	38	35	39	165

Expected Frequency (E)

3.8	8.1	9	7.8	8.7	37
6.8	14.4	15	14.0	15.6	66
3.5	7.4	8	7.2	8.0	34
2.9	6.1	6	5.9	6.6	28
17	36	38	35	39	165

CHI – SQUARE (X²)

$$(X^2) = \sum (O-E)^2/E$$

Where,

O = observed frequency

E = expected frequency

$$E = RT \times CT / GT$$

Where,

RT = Row Total

CT = Column Total

GT = Grand Total

O	E	(O-E) ²	$\sum (O-E)^2/E$
7	3.8	10.24	2.69
8	6.8	1.44	0.21
2	3.5	2.25	0.64
0	2.9	8.41	2.90
15	8.1	47.61	5.88
13	14.4	1.96	0.14
8	7.4	0.36	0.05
0	6.1	37.21	6.10
8	9	1.00	0.11
14	15	1.00	0.07
8	8	0.00	0.00
8	6	4.00	0.67
7	7.8	0.64	0.08
16	14	4.00	0.29
7	7.2	0.04	0.01
5	5.9	0.81	0.14
0	8.7	75.69	8.70
15	15.6	0.36	0.02

9	8	1.00	0.13
15	6.6	70.56	10.69
χ^2	39.51		

Degree of Freedom (v) = (r-1) (c-1)

$$= (4-1) (5-1)$$

$$= 12$$

Calculated Value (χ^2) = 39.51

Tabulated Value (χ^2 0.95) = 21.026

Since the calculated chi-square value exceeds the tabulated value, the Null Hypothesis is rejected. Based on the value it is indicated that there is an association between the experience of the respondents and the frequency of their participation in the career development programs and trainings. The results are statistically significant.

FINDINGS

This study analysed faculty members' awareness and understanding of the available career development programs and trainings. The results indicate that faculty members are highly aware of these programs and training opportunities. Those who have completed their their probationary period receive finding from their institution for the training based on the assessed needs.

Faculty members with less than five years of experience strongly agreed that these programs and training supports the development of essential skills for their careers. Those with less than two years of experience agreed that participation in these programs boosts their confidence and self-esteem. Similarly, Faculty members with more than five years of experience indicated that their participation in these programs is voluntary.

Newly joined faculty members strongly agreed that this career path helps them establish time-bound plans and guides them in taking timely and appropriate action to overcome obstacles. Additionally, it provides opportunities to strengthen their profile.

The faculty also noted that it encourages a positive attitude and fosters support among colleagues and students. Among faculty with five years of experience, 51% agreed that participation in programs and training is a key criterion for receiving increments and promotions. Faculty members from all the experience groups show interest in cost-benefit and they eager get valuable certifications. Free programs are particularly appealing to those in the income group below 25,000. Furthermore, 39% of the respondents indicated that the duration of the programs and training influenced their participation

SUGGESTIONS AND CONCLUSION

Higher education institution face the challenge of insufficient trained faculty due to a highly competitive environment. Well-experienced and highly qualified faculty members often seek positions at institutions that offer higher salaries. This creates a significant challenge for the institutions that provide only minimum or average pay. Additionally many of these institutions are under pressure for accreditation from the National Assessment and Accreditation Council (NAAC).

Faculty members are encouraged to participate in career development programs and training; however, many feel that their income does not adequately cover the costs associated with registration, transportation, and other expenses related to these programs. To address this issue, higher education institutions should invest in supporting newly appointed faculty in their career advancement. Institution can help by providing on-duty leave and adjusting class schedules, allowing faculty to attend these programs and trainings.

The program organisers should consider scheduling events during end semester examinations and vacations to minimise disruptions to faculty schedules. Additionally, organisers should take steps to ensure the transportation arrangements are in place and that venues are easily accessible. It is also crucial to address technical issues, such as internet connectivity, projector malfunctions, presentation errors, and sound system problems, before the program begin. Organisers should dedicate more time to selecting relevant topics, identifying knowledgeable resource person, and providing hands-on training. Listening to considering the expectations of the participants will greatly contribute to the success of the programs and the reputation of the institution among the participants.

The findings highlight the importance of career development programs and training, as well as faculty members' perception of them. By implementing these suggestions, higher education institutions can achieve their goals and better serve society, particularly the younger generation. Organising such programs and training will surely benefit both faculty members and the student community

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The Role of Institutional Politics and Employee Power in Shaping the Quality of Higher Education

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ABSTRACT

This study considered organizational politics as the source of the climatic change in their behavior and outcomes of teaching facilities in the organization (colleges). By combining perception of organizational politics (pops) job involvement organizational commitment and quality education theory a moderating model has being developed by the researcher. This model brings out the relationship between perception of organizational politics and behavior among the employees in the organization. Examine employees work out come and also increase qualified teachers. To identify the problem faced by the employees regarding climatic change due to political behavior in the working atmosphere. The results open out that organizational politics has both positive and negative influence over the outcomes and behavior of the employees. Perception of organizational politics has a direct and indirect relationship with the behavior such as job involvement and organizational commitment. This makes the employees down and stressful but they overcome this politics by themselves in the working condition. Due to the various affecting factors outcome of the teaching facilities will also affected. This will have a greater impact in the quality of education and the next generation will be affected to a greater extend.

KEYWORDS : *Organizational politics, Job satisfaction and job commitment, Quality of education, Teaching facilities.*

INTRODUCTION

Education is the institution through which values are transmitted to the societal member. The importance of teaching faculty in the education system are nation building, making of good citizen inculcating the cultural heritage to the younger generation. The quality comes from the personal insight and the quality of their professional preparation (Duggal 2005). Sustainable Development Agenda (SDG 4) is to ensure that all have good education from schooling to higher education and this goal connects to the present discussion of education policy, which is focused on a number of different indicators and standards. (Ozga 2012; Cardoso and Steiner-Khamisi 2017). The researcher covers areas such as (i) behavioral of employees in a political atmosphere and how it affects the quality of education (ii) Commitment of employees in political circumstance. (iii) Identify the problem faced by the employees regarding climatic change due to political behavior in the working atmosphere

Organizational politics is significant because of the impact it may have on outcomes including job satisfaction, employee motivation, organizational commitment, job performance, and organizational citizenship (Donald, Bertha & Lucia,

2016). Keeping workers committed has become a key difficulty for both private and public sector firms in today's uncertain work climate, when employees confront increased uncertainty in their everyday activities and a decreasing sense of job security. (Nidhi & Perna, 2015; Gotsis & Kortezi, 2010). The influence of organizational Political concerns on our lives, both directly and indirectly, is substantial. (Opoku and Arthur 2018). Organizational politics is significant because of the impact it may have on important workplace outcomes including job satisfaction, employee motivation, organizational commitment, job performance. (Donald, Bertha & Lucia, 2016). With the political climate shifting, the quality of education at universities is under doubt. For the sake of the local ecosystem and standard of living, it is imperative that the next generation get a top-notch education. (Swaminathan, 2001). Adjustment to the political climate at educational institution may be made and the measures needed to achieve the SDG of providing a quality education can be recognized.

LITERATURE REVIEW

Effects of climate change lie in many criteria in which the researcher had concentrated on very few areas such as

employee commitments and behavior of the employees in the political atmosphere.



Politics and education quality

Joseph, Stephen -. 2015 the researcher found that Education institution and working facilities are face more pressure in their work life as they have to fulfill the expected role in the society and long term sustainable development change. What should be taught are decided on the heavy influenced by the political society? Political action become a well-known force in education system throughout the nation. This paper explores that the various ways in which the teachers in higher education are survive in perceived threat of political interference. Due to the political intervention the quality of the education will be a questionable one. The result of the study influenced that the teachers should be comes out to terms with the reality of politics what they are facing in the curriculum and find ways to function optimally in any given political context.

Politics and job satisfaction

Iqbal Khan, Tariq, Rudsada Kaewsang-on, Mubashar Hassan Zia, Sheraz Ahmed, and Abdul Zahid Khan. (2020) researcher found that worker's views on politics had an impact on their well-being and performance on the workplace. Age moderation in political perspective is also discussed. It was shown that political awareness positively with stress at work but has no impact on job happiness. The findings show that age matters in politics, with both younger and older generations feeling the effects of politics and seeing a decline in work satisfaction as a consequence.

Politics and organizational commitment

Shaq, S Adia I. (2015) this study through a light on the organization politics and loyalty to the company (organization commitment) as a whole and also some other factors such as satisfaction of job and plans to leave the job. Employees' dedication drops as a direct consequence of their exposure to what they see as political manoeuvring inside the organization. Additionally, it was shown that feeling of dissatisfaction with one's employment and lack of dedication to the organization were correlated with an individual's opinion.

OBJECTIVE

1. To study the better, understand how individuals inside an

organization see internal politics and conduct.

2. Employees work out come and also increase the supply of qualified teacher in Trichy colleges.
3. To identify the problem faced by the employees regarding climatic change due to political behavior in the working atmosphere.

The research methodology for investigating the mediating

RESEARCH QUESTION

1. To what extend teaching faculty are involved in organizational politics and how it affects the quality of education?
2. What extend the qualified teachers are there in the university and how far the qualified teacher provides quality education that reflects the SDG 4?

STATEMENT OF THE PROBLEM

As discussed in section that the higher education is essential in human life. Education itself plays an important role in and higher education plays more important role in promoting economic growth and development. Considering the educational sector, teachers are the backbone of any educational institution. The efficiency and effectiveness of an educational institute are not possible without involving the teachers. For this faculty needs to move beyond the job descriptions, voluntarily make extra efforts and voluntarily contribute their abilities, for the interest of the educational institute. These behaviors not only help the faculty members and students but also benefit the institution as a whole. Subsequently, employees are motivated to extend more effort to the organization who is satisfied with their job. Job satisfaction can build up a strong involvement in, and emotional attachment of employee to their organization which, in turn, can foster better performance. There is a favorable correlation between job satisfaction and employee's behavior. However, when the political climate of the educational sectors changes, such as in the field of education. People who like their professions tend to be dedicated to their work and exhibit good organizational citizenship behaviors. Therefore, the purpose of this research is to explore the connection between high-quality education for sustainable development and global citizenship, as well as how workers perceive the politics and conduct of their organization's leadership.

RESEARCH METHODOLOGY

Sampling size

The population size of Arts college teachers in Trichy city is 3479 from 18 Colleges researcher have selected 5 colleges out of 18 for this paper. The sample size will be 175 from the population size Data will be collected from the respondents

through a structured questionnaire from the Arts and science college faculties of Trichy city.

Source of Data Collection

Sampling Method

The potential respondents are basically selected from employee of different higher educational institutions at different categories. Random sampling and stratified random sampling will be used for this research and the sample included employees from all genres like higher officials, professors.

Data was collected through both primary and secondary sources. The primary source of information was through a predetermined questionnaire. Primary data was collected through distributing the questionnaire by the researcher (Electronic Medium and paperback). Secondary source, such as reference books, peer-reviewed journals, and online database, was mined for information.

Tools for Analysis

1. Correlation
2. Regression

Model on organizational politics and how it works in the higher educational institutions.

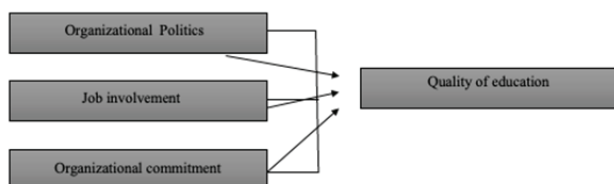


Fig 1: Organizational politics whether it affects the job involvement of the employees

POps and job involvement scale are taken into consideration to measures the organizational politics and job involvement.

Table 1: POPS

mean	2.26	3.95	3.23	2.54	2.71	2.97	2.57	3.13	2.22	4.24
SD	1.13	0.77	0.51	1.41	1.44	0.60	0.87	0.53	1.04	0.74

Table 2: Job Involvement

me	4.	4.	4.	4.	1.	3.	4.	4.	4.	2.	3.	4.
an	2	2	2	2	9	5	4	2	1	1	1	2
	1	3	3	2	7	5	6	6	4	0	5	3
SD	.5	.6	.6	.7	1.	.8	.6	.6	.6	.9	.5	.6
	6	4	3	8	0	4	1	1	3	4	0	5

Mean and standard deviation of perception of organizational politics and job involvement Correlation between organizational politics and job involvement

HO: there is no relationship between organizational politics and job involvement

H1: there is relationship between organizational politics and job involvement

From the above table it is inferred that the researcher had come to a conclusion that most of the variables are negatively correlated and in some cases they are positively correlated. Only few are negative correlation this is because the respondents were not able to work properly due to the politics in the organization it was high and common in all age group people. In most of the case it has a positive correlation and have a positive politics, people were able to cope up with the politics in the organization and they were able to work involvedly in the political atmosphere. In this case people were used to the politics in the working place and they adopt themselves to work in the circumstance where politics evolved.

To know the relationship between the age and organizational commitment using age and organizational commitment scale are used to know the relationship between both. We use regression

HO: There is no significant impact between age and organizational commitment.

H1: There is significant impact between age and organizational commitment.

Table 3 ANOVA

Model	Sum of Squares	df	Mean Square	F	Sig.
1 Regression	6.149	8	.769	18.42 ^a	.19
Residual	90.000	166	.542		
Total	96.149	174			

The hypothesis tests if age of the employees carries as significant impact on organizational commitment. The dependent variable age was regressed on predicting variables to test the hypothesis. Age significantly predicted organizational commitment, $F(1, 1418) p < 0.001$ which indicate that age can play a significant role in shaping ($b = -.096, .100, -.019, .044, -.087, -.146, .147, -.011, p < .001$). Majority of the respondents are between the age group of 30-40 it is clear that some of them have positive effects and some have negative effects i.e., it has equal positive and negative influence particular in the mention the above age group have a

greater influence on organizational commitment it is effected due to organizational politics.

Table 4

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	1.943	.660		2.944	.004
OUTCOMES OF POLITICAL BEHAVIOUR (ORGANIZATION COMMITMENT) (I would be very happy to spend the rest of my career with this Organization)	-.106	.101	-.096	-1.049	.296
OUTCOMES OF POLITICAL BEHAVIOUR (ORGANIZATION COMMITMENT) (I enjoy discussing my organization with people outside it.)	.091	.115	.100	.795	.428
OUTCOMES OF POLITICAL BEHAVIOUR (ORGANIZATION COMMITMENT) (I really feel as if this organization's problems are my own)	-.018	.122	-.019	-.148	.883
OUTCOMES OF POLITICAL BEHAVIOUR (ORGANIZATION COMMITMENT) (I think that I could easily become as attached to another organization as I am to this one)	.039	.082	.044	.477	.634
OUTCOMES OF POLITICAL BEHAVIOUR (ORGANIZATION COMMITMENT) (I do not feel like 'part of the family' at my organization.)	-.076	.082	-.087	-.922	.358
OUTCOMES OF POLITICAL BEHAVIOUR (ORGANIZATION COMMITMENT) (I do not feel 'emotionally attached' to this organization)	-.162	.097	-.146	-1.678	.095
OUTCOMES OF POLITICAL BEHAVIOUR (ORGANIZATION COMMITMENT) (This organization has a great deal of personal meaning for me)	.181	.099	.147	1.821	.070
OUTCOMES OF POLITICAL BEHAVIOUR (ORGANIZATION COMMITMENT) (I do not feel a strong sense of belonging to my organization)	-.066	.067	-.011	-.094	.926

FINDING AND SUGGESTION

- The study investigates the job involvement it has some positive and negative influence on the employee's behavior. It doesn't come to a fully negative influence and fully positive influence. It has both cause and effect. To some extend involvement of job is affected due to politics in working atmosphere and on the other extend it have some positive politics which helps the people to work dedicated towards their job
- The researcher had found that it has a direct and indirect relationship between age of the working employees and organizational commitment and also indirect influence by politics in the working atmosphere. People at young age between 30-40 have a greater influence due to politics because of the influence of politics the employees have both positive and negative aspects to some level they are commitment towards the organization, in some cases they may be influenced due to the power of the higher authorities, other impacting factors such as experience of the employees, higher level of salary etc. due to this the organization commitment of the working faculty will go down because of the influence in the above mention factors. Some of the important factors in which they are

affected should be found out by the organization. Some self-analysis should be done to overcome the politics

- Employees also face may problems due to the politics in the organization they fell stressed, unsatisfied working environment, low in the performance of the employees etc. these are the some of major problems faced by the employees. Some of them are over comes by themselves in some case they may lead to positive politics also which pave way to encourage employees and motivate them to work hard.
- From the condition of the outcomes and behavior of the teaching faulty they have both positive and negative influence due to the politics evolved in the organization or colleges it was in the ratio of 50-50 that it had both positive and negative influence the quality of teaching and equipped teachers will be a questionable one. It will be in the same ratio as quality of the education will be affected to a greater extend. The government and the educational institutions should take some proper measure in the quality of education and quality of teaching facilities. The rules and regulation towards the education should be framed even wiser than now. So that the upcoming generation will be in the right path with quality education. When the politics is overruled all the factors will be get affected if it is in the structured way we can provide a quality education to the younger generation.

RESULT

Practical implication: To get above the politics in the workplace, the government's colleges and education department has to act with some great initiative. The education department of government should look after the standard of instruction. Our life depends on education; so, the quality of the education must be accessible to everyone. However, there is no place without politics as in the case of the field of education. This causes a change in the educational environments' temperature. The political environment in the educational institutions causes climatic changes; so, it is possible to solve these changes and implement some required actions to guarantee a quality education and also detect the significant changes in the climate of educational institutions. The changes in the climate experienced in the educational field will influence the output of the work. This project will enable the society to greatly extend in analysis quality of education in the higher education institution in a political environment. This article had opened doors for other researchers about political issues in higher education and quality of instruction. Future researchers should take into account more outcomes so that we may have a depth in the topic and produce fresh

results to enhance our working environment without politics and raise the level of education with plays the key importance in the younger generation.

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Customers' Awareness of the Customer Services Provided by Public and Private Sector Banks in Thanjavur District - An Analysis

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ABSTRACT

The main aim of this study is to evaluate Thanjavur district consumers' awareness of public and private sector banks' offered customer services. The aim of the study was fulfilled by descriptive and exploratory research techniques. Moreover, the sample banks and sample responders were determined by means of the multi-stage random sampling method. Within the research region, there are seven private sector banks with 83 branches in urban and rural areas and eight public sector banks with 161 branches. The population of the study consisted in eight public and seven private sector banks overall. Time restrictions also led the researcher to choose thirty branches—that is, one from rural and another from urban—each two branches from public and private sector banks. The sample branches were chosen by simple random sampling. Policy problems caused the sample bank officials to withhold the client list. The population of the research was thus regarded as unknown. Consequently, every ten consumers from sample branches were identified as sample responders by applying simple random sampling methods. Consequently, the sample consisted in three hundred clients overall. According to the survey, most of the sample consumers have had accounts in the banks for six to ten years, regardless of public or private sector banks; they have accounts for loans and savings. The degree of awareness of different customer services offered by public and private sector banks found that, independent of the banks, most of the sample consumers have a medium and low level of awareness. Moreover, the correlation between sample customer level of awareness about different customer services supplied by banks reveals that the customers' age, education, and occupation dominated their level of awareness independent of banks

KEYWORDS : *Customer services, Customer awareness, Public and private sector banks.*

INTRODUCTION

In today's competitive marketplace, establishing and During the last three decades, the service industry in the world has remarkably increased. Many companies have started to provide a variety of customer services to retain their customers; in particular, the banking industry has entered into new phenomena. The banking sector in India has changed significantly after economic liberalisation. After the introduction of globalisation, the Indian banking industry moved international market. Many foreign banks started to enter the Indian banking industry, and also Indian banks started to provide various types of customers services to attract customers like online banking, mobile banking, debit card, credit card, different kinds of loans, different kinds of deposits, SMS alerts, home banking, currency services, mutual funds, buying and selling of stocks and shares and more. These services aim to provide better and

more convenient services to customers to retain and attract new customers.

STATEMENT OF THE PROBLEM

The Indian banking industry was moved to international standards after the introduction of globalisation. Among the service industry, the banking industry is one of the industries that customers meet daily. All types of banks in India provide different kinds of banking services to their customers. In particular, both public and private sector banks provide various customer services to attract and retain customers in the global competitive banking industry. However, the banks are faced with several problems while providing better and more convenient services to customers, like high cost of investment for ATM points, technological advancement, extra labour, high cost of machinery and others. At the same time, many studies found that the majority of bank customers in India are still not availed of all the customer services

provided by banks, particularly in rural areas. Against this backdrop, this study has been conducted.

OBJECTIVE OF THE STUDY

The prime objective of this study is to identify the level of customer awareness of customer services provided by public and private sector banks.

RESEARCH METHODOLOGY

Descriptive and exploratory research methods were used to fulfil the research objective. Further, the multi-stage random sampling technique was used to identify the sample banks and sample respondents. In the study area, there are 8 public sector banks with 161 branches and 7 private sector banks with 83 branches in rural and urban areas. A total of 8 public and 7 private sector banks were treated as the population of the study. Further, due to time constraints, the researcher selected 30 branches for sample branches, i.e. each two branches from sample public and private sector banks (one from rural and another from urban). The simple random sampling technique was used to select the sample branches. The sample bank officials did not give the list of customers due to policy issues. Thus, the population of the study was considered unknown. Therefore, every 10 customers from sample branches were determined as sample respondents using simple random sampling techniques. Hence, a total of 300 customers was used as sample customers.

RESULTS AND DISCUSSION

Knowing the demographic profile and bank-related data of sample consumers helps one evaluate their degree of awareness of consumer services supplied by public and private sector banks. Five points scaling approach was used to examine the degree of knowledge of the utilization of customer services supplied by sample banks: very high, moderate, medium, low and very low. Moreover, the link between demographic and bank-related factors of sample consumers and their degree of awareness about several kinds of customer services given by banks was investigated using the Multiple Linear Regression technique. The following Tables show the analysis findings.

Table 1: Demographic profile and bank-related variables of sample customers

S. N	Particulars	Public sector banks	Private sector banks	Total
Demographic profile				
1.	Age			
	Upto 30 years	26 (16.25)	31 (19.38)	57 (19.00)

	31-40	41 (25.63)	50 (31.25)	91 (30.33)
	41-50	54 (33.75)	49 (30.62)	103 (34.34)
	Above 50 years	39 (24.37)	10 (6.25)	49 (16.33)
	Total	160 (100)	140 (100)	300 (100)
2.	Gender			
	Male	68 (42.50)	96 (68.57)	164 (54.67)
	Female	92 (57.50)	44 (31.43)	136 (45.33)
	Total	160 (100)	140 (100)	300 (100)
3.	Education background			
	No formal education	19 (11.88)	02 (1.43)	21 (7.00)
	School education	76 (47.50)	45 (32.14)	121 (40.33)
	Graduate	49 (30.62)	74 (52.86)	123 (41.00)
	Professional / Technical	16 (10.00)	19 (13.57)	35 (11.67)
	Total	160 (100)	140 (100)	300 (100)
4.	Occupation			
	Agriculturist and wage labour	79 (49.38)	22 (15.71)	101 (33.67)
	Government employee	21 (13.12)	12 (8.57)	33 (11.00)
	Private employee	39 (24.37)	28 (20.00)	67 (22.33)
	Business and professionals	11 (6.88)	64 (45.72)	75 (25.00)
	Others	10 (6.25)	14 (10.00)	24 (8.00)
	Total	160 (100)	140 (100)	300 (100)
5.	Income per month			
	Upto Rs.10,000	73 (45.63)	68 (48.57)	141 (47.00)
	Rs. 10,001 to Rs.25,000	70 (43.75)	61 (43.57)	131 (43.67)
	Rs.25,001 to Rs.40,000	10 (6.25)	5 (3.57)	15 (5.00)
	Above Rs.40,000	7 (4.37)	6 (4.29)	13 (4.33)
	Total	160 (100)	140 (100)	300 (100)
Bank related variables				
6.	Number of years account hold with bank			
	Upto 1 year	10 (6.25)	12 (8.57)	22 (7.33)
	1 – 5 years	56 (35.00)	51 (36.43)	107 (35.67)
	6 – 10 years	75 (46.88)	72 (51.43)	147 (49.00)
	Above 10 years	19 (11.87)	5 (3.57)	24 (8.00)
	Total	160 (100)	140 (100)	300 (100)
7.	Purpose of account hold with bank			
	Savings and Investments	55 (34.38)	25 (17.86)	80 (26.67)

	Loans and advances	58 (36.25)	61 (43.57)	119 (39.67)
	Business	35 (21.87)	44 (31.43)	79 (26.33)
	Others	12 (7.50)	10 (7.14)	22 (7.33)
	Total	160 (100)	140 (100)	300 (100)

Source: Compiled from primary source.

Figures in parenthesis are percentage to column total

Age Distribution

- The sample customers from public sector banks showed a higher percentage (33.75%) in the 41-50 years age group, followed by 31-40 years (25.63%) and above 50 years (24.37%).
- In private sector banks, the largest proportion (31.25%) belonged to the 31-40 years age group, with 30.62% in the 41-50 years category, and only 6.25% in the above 50 years category.
- Overall, the age group 41-50 years had the largest share across both sectors (34.34%), followed by 31-40 years (30.33%). The younger age groups (up to 30 years) accounted for 19%, while the above 50 years category had the least representation (16.33%).

Gender

- Public sector banks had a majority of female customers (57.50%), while male customers made up 42.50%.
- In private sector banks, the gender distribution was reversed, with a larger proportion of male customers (68.57%) and female customers comprising 31.43%.
- Across the total sample, male customers made up 54.67%, and female customers accounted for 45.33%.

Education Background

- A significant portion of customers in both sectors had school-level education, with 47.50% in public sector banks and 32.14% in private sector banks.
- Public sector banks had a larger proportion of customers with no formal education (11.88%) compared to private sector banks (1.43%).
- Graduate customers represented 30.62% in public sector banks and 52.86% in private sector banks, leading to a total of 123 (41%) graduates across the sample.
- The least represented educational category was professional/technical education, with 10% in public sector banks and 13.57% in private sector banks.

Occupation

- The most common occupation in public sector banks was agricultures and wage laborers, constituting 49.38% of the sample, while in private sector banks, this group was significantly smaller (15.71%).
- Government employees and private employees were evenly distributed across both sectors.
- Business owners and professionals made up a large portion of private sector bank customers (45.72%) compared to just 6.88% in public sector banks.
- The "Others" category was more prominent in private sector banks (10%) than in public sector banks (6.25%).

Income per Month

- Customers from both banks primarily fell into the income range of up to Rs.10,000, accounting for 45.63% in public sector banks and 48.57% in private sector banks.
- The second-largest group was in the Rs.10,001 to Rs.25,000 range, with 43.75% in public sector banks and 43.57% in private sector banks.
- Higher income categories (Rs.25,001 to Rs.40,000 and above Rs.40,000) had a minimal representation, accounting for only 5% and 4.33%, respectively, across the total sample.

Number of Years Account Held with the Bank

- Customers who had held accounts for 6-10 years made up the largest group, with 46.88% in public sector banks and 51.43% in private sector banks, totaling 49% across both sectors.
- Public sector banks had more customers with accounts for up to 1 year (6.25%) and above 10 years (11.87%) compared to private sector banks.
- Private sector banks had a slightly higher proportion (8.57%) of customers with accounts for up to 1 year compared to public sector banks (6.25%).

Purpose of Account Held with the Bank

- The most common purpose for holding an account was for savings and investments in public sector banks (34.38%), while private sector banks had more customers using accounts for loans and advances (43.57%).
- Business accounts were more common in private sector banks (31.43%) compared to public sector banks (21.87%).

- Other purposes, such as miscellaneous reasons, had a smaller share, with 7.50% in public sector banks and 7.14% in private sector banks.

In summary, demographic and bank-related characteristics varied significantly across public and private sector bank customers, with public sector banks attracting more female customers, lower-income individuals, and those in agricultural or wage labor occupations, while private sector banks had more male customers, higher-income individuals, and a larger proportion of business professionals.

Table 2: Customers level of awareness of customer services provides by sample public and private sector banks

S N	Customer Services	Level of awareness	Public sector banks	Private sector banks
1.	Payment services	High	42 (26.25)	48 (34.29)
		Medium	86 (53.75)	88 (62.86)
		Low	32 (20.00)	4 (2.86)
		Total	160 (100)	140 (100)
2.	Deposit service	High	29 (18.13)	41 (29.29)
		Medium	102 (63.75)	82 (58.57)
		Low	29 (12.12)	17 (12.14)
		Total	160 (100)	140 (100)
3.	Accounts services	High	38 (23.75)	25 (17.86)
		Medium	81 (50.63)	65 (46.43)
		Low	41 (25.62)	50 (35.71)
		Total	160 (100)	140 (100)
4.	Debit and Credit cards	High	29 (18.12)	38 (27.14)
		Medium	54 (33.75)	79 (56.43)
		Low	77 (48.13)	23 (16.43)
		Total	160 (100)	140 (100)
5.	Loans and advances	High	34 (21.25)	30 (21.43)
		Medium	64 (40.00)	54 (38.57)
		Low	62 (38.75)	56 (40.00)
		Total	160 (100)	140 (100)
6.	Online banking	High	24 (15.00)	36 (25.71)
		Medium	52 (32.50)	55 (39.29)
		Low	84 (52.50)	49 (35.00)
		Total	160 (100)	140 (100)
7.	Mobile banking	High	25 (15.63)	49 (35.00)
		Medium	59 (36.88)	71 (50.71)
		Low	76 (47.50)	20 (14.29)
		Total	160 (100)	140 (100)
8.	Securities services	High	8 (5.00)	19 (13.57)

	Securities services	Medium	55 (34.38)	48 (34.29)
		Low	97 (60.62)	73 (52.14)
		Total	160 (100)	140 (100)
9.	Others	High	25 (15.62)	21 (15.00)
		Medium	39 (24.38)	37 (26.43)
		Low	96 (60.00)	82 (58.57)
		Total	160 (100)	140 (100)

Source: Compiled from primary source

Figures in parenthesis are percentage to column total

Payment Services

- In public sector banks, 26.25% of customers had a high level of awareness, while the majority (53.75%) had a medium level of awareness. A significant portion (20%) reported low awareness.
- In private sector banks, 34.29% of customers had a high level of awareness, with 62.86% having a medium level. Only 2.86% had low awareness.
- Overall, private sector bank customers showed higher awareness levels across all categories compared to public sector bank customers.

Deposit Services

- Public sector bank customers had a relatively lower level of awareness, with only 18.13% reporting high awareness, while 63.75% had medium awareness. 12.12% of customers indicated low awareness.
- In private sector banks, the high awareness group was larger (29.29%), with 58.57% having medium awareness and 12.14% low awareness.
- Private sector bank customers exhibited better awareness of deposit services, particularly in the high and medium awareness categories.

Account Services

- In public sector banks, 23.75% of customers reported high awareness, with the largest group (50.63%) indicating medium awareness. A notable percentage (25.62%) had low awareness.
- Private sector bank customers showed a slightly lower high awareness percentage (17.86%), but the medium awareness group (46.43%) was comparable. The low awareness group was larger in private banks (35.71%).
- Both sectors showed similar trends in account services awareness, with public sector customers being slightly more aware than those in the private sector.

Debit and Credit Cards

- Public sector bank customers had lower awareness, with only 18.12% reporting high awareness. The medium awareness group was 33.75%, while 48.13% had low awareness.
- In private sector banks, 27.14% had high awareness, with 56.43% reporting medium awareness and only 16.43% had low awareness.
- Private sector banks showed significantly higher awareness levels, particularly in the high and medium awareness categories.

Loans and Advances

- Awareness in public sector banks was evenly distributed, with 21.25% reporting high awareness, 40% with medium awareness, and 38.75% with low awareness.
- In private sector banks, the awareness levels were more concentrated in the medium category (38.57%) and low category (40%), with only 21.43% reporting high awareness.
- Awareness regarding loans and advances was relatively consistent across both sectors, but private sector bank customers had a higher percentage in the low awareness category.

Online Banking

- Public sector bank customers had a significant proportion (52.50%) with low awareness of online banking. Only 15% reported high awareness, while 32.50% had medium awareness.
- In private sector banks, 25.71% had high awareness, and 39.29% reported medium awareness. The low awareness group was smaller at 35%.
- Private sector bank customers showed significantly higher awareness of online banking services compared to their public sector counterparts.

Mobile Banking

- In public sector banks, 15.63% of customers reported high awareness, while 36.88% had medium awareness. The majority (47.50%) had low awareness.
- Private sector bank customers exhibited a much higher awareness of mobile banking, with 35% having high awareness, 50.71% medium awareness, and only 14.29% low awareness.
- Private sector bank customers were notably more aware of mobile banking services.

Securities Services

- Public sector bank customers had low awareness of securities services, with 60.62% reporting low awareness and 5% having high awareness. The medium awareness group was 34.38%.
- Private sector bank customers had better awareness, with 13.57% reporting high awareness, 34.29% medium awareness, and 52.14% low awareness.
- Private sector banks performed better in securities services awareness, though the majority still reported low awareness in both sectors.

Other Services

- Public sector bank customers reported 15.62% high awareness, with 24.38% medium awareness and 60% low awareness.
- In private sector banks, 15% had high awareness, 26.43% had medium awareness, and 58.57% reported low awareness.
- Awareness levels for other services were similar across both sectors, with low awareness being the most common response.

Overall Observations

- Private sector bank customers generally exhibited higher levels of awareness compared to public sector bank customers across most services.
- Public sector bank customers were more likely to report low awareness, particularly in services like mobile banking, online banking, and securities services.
- Medium awareness was the most common response in both sectors, especially for services like payment, account, and loan services.

Hence, the analysis result reveals that irrespective of the bank, the majority of the sample customers have a medium and low level of awareness about the various customer services provided by public and private sector banks in the study area.

Table 3: Customers' level of awareness of different customers services provided by public and private sector banks - Multiple Linear Regressions

S. N	Variables	Public sector banks	Private sector banks
Demographic variables			
1.	Age	-2.841**	-2.903**
2.	Gender	0.257	1.711

3.	Education	2.921**	3.016**
4.	Occupation	2.866**	2.905**
5.	Income	1.254	2.015
Bank related variables			
6.	No. of years account held	0.894	-2.014
7.	Purpose of account held	-1.803	1.115
	N	160	140
	Constant	13.670	12.089
	R square value	0.569	0.578

Source: Computed from primary data

** Significant at 5 percent level.

CONCLUSION AND RECOMMENDATIONS

It can be concluded from the analysis that, irrespective of public and private sector banks, most of the sample customers have accounts in banks of 6 to 10 years and have accounts with banks for savings and loans. The sample customers' level of awareness of various customer services provided by public and private sector banks revealed that irrespective of the banks, the majority of the sample customers have a medium and low level of awareness. Further, the relationship between sample customer level of awareness about various customer services provided by banks shows that irrespective of the customers' age, education and occupation play a dominant role in their level of awareness. Hence, the following suggestions have been given.

The study result indicates that the lower age group, higher educated and higher level occupational customers only have a higher level of awareness about various customer services provided by sample public and private sector banks. Therefore, both banks should concentrate on this issue to attract and give awareness to all customers.

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Impact of Market Sentiment on Investment Decisions: The Mediating Role of Investor Confidence

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ABSTRACT

The study investigates the impact of market sentiment on investment decisions, focusing on the mediating role of investor confidence. Market sentiment, reflecting the overall attitude and emotions of investors towards financial markets, significantly influences individual investment decision making. The study investigates into how factors such as media exposure, economic news, and peer advice contribute to forming market sentiment and investor confidence. Realizing the link between these elements influence decision-making. The study utilized 465 individual investors in Tiruchirappalli district, Tamilnadu. The study used causal research design and purposive sampling technique. Percentage analysis, One-Way ANOVA, Post-hoc test, and structural equation modelling are used for data analysis. Results proved that media exposure, economic news, and peer advice have significant effect on market sentiment. Market sentiment has direct and significant effect on investment decisions. Investor confidence has no mediation influence between market sentiment and investment decisions. Age, academic status, monthly earnings and occupation have significant effect on media exposure, economic news, peer advice, market sentiment, investor confidence, and investment decisions. The findings are helpful to effective investment decision-making among individual investors.

KEYWORDS : *Media exposure, Economic news, Peer advice, Market sentiment, Investor confidence, Investment decisions.*

INTRODUCTION

The movement of equity share prices is mainly depended on logical and psychological factors prevailing in the stock market. Market is driven by both rational and irrational signals, the signals guiding the investors to make profitable investment decisions. Individual investors are small investors they have limited opportunity than high net-worth individuals or institutional investors. The decision making behaviour of individual investors are totally different from institutional investors. They mostly adhere sentimental dimensions prevailing in stock market. They often consider several sentimental information for investment decision making. Therefore, investment decisions made by individual investors are affected by various external and internal factors, with market sentiment being a main determinant. Market sentiment reflects the collective mood or attitude of investors toward the equity share investments, and it can influence between optimism and pessimism, directly affecting investor behavior (Singh, 2021). In periods of optimism, investors are more likely to buy stocks, anticipating price increases,

while in times of pessimism, they may sell off stocks to avoid potential losses. In this way, the study explores how market sentiment impacts the investment decisions of individual investors, emphasizing how emotions, media exposure, and economic news form their actions.

HYPOTHESIS DEVELOPMENT



Fig. 1: Conceptual Framework

Based on extensive review, the consequent hypotheses are offered to test.

H1.1: Antecedents have significant effect on media exposure, economic news, peer advice, market sentiment, investor confidence, and investment decisions.

H1.2: Media exposure, economic news, and peer advice have significant effect on market sentiment.

H1.3: Market sentiment has significant effect on investment decisions.

H1.4: Investor confidence has significant mediation effect on market sentiment and investment decisions.

H1.5: Socio-Economic profile has significant effect on media exposure, economic news, peer advice, market sentiment, investor confidence, and investment decisions.

PURPOSE AND METHODS

The study is planned to assess the impact of market sentiment on investment decisions of individual investors. The study especially focused on equity market investments, hence, investor confidence is employed as mediator between market sentiment and investment decisions. The study is performed with a sample size of 465 individual investors in Tiruchirappalli district, Tamilnadu. The samples are identified through purposive sampling procedure. Causal research design is utilized to assess the cause-and-effect relationship among research variables. A well-structured survey questionnaire is designed and presented among individual investors to collect primary responses. Statistical techniques such as, percentage analysis, One-Way ANOVA, Post-hoc test, and structural equation modelling are executed for data analysis.

RESULTS

Socio-Economic Profile of Individual Investors

The socio-economic profile is analyzed in Table 1

Table 1: Analysis of Socio-Economic Profile

Profile	Distribution	Number	Percentage
Gender	Male	355	76.3%
	Female	110	23.7%
Age	Below 30 years	107	23.0%
	30 – 50 years	218	46.9%
	Above 50 years	140	30.1%
Academic Status	School	276	59.4%
	Degree	139	29.9%
	Professional	50	10.8%
Monthly Earnings	Less than Rs.25,000	165	35.5%
	Rs.25,000 – 50,000	172	37.0%
	More than Rs.50,000	128	27.5%
Occupation	Private employee	78	16.8%
	Government employee	161	34.6%
	Businessmen	226	48.6%

Table 1 reveals the demographic characteristics in terms of gender, age, academic status, monthly earnings, and occupation of individual investors. Among the individual investors, a significant majority (76.3%) are male, while females represent 23.7%. In terms of age distribution, almost half (46.9%) of investors are between 30 - 50 years old, followed by 30.1% who are over 50 years, and 23% are under 30. Academic background shows that most participants (59.4%) have a school-level education, 29.9% hold a degree, and 10.8% are professionals. Monthly earnings shows that 37% earn between Rs.25,000 - Rs.50,000, 35.5% earn less than Rs.25,000, and 27.5% earn more than Rs.50,000. In terms of occupation, 48.6% are businessmen, 34.6% are government employees, and 16.8% are private employees.

Impact of Market Sentiment on Investment Decisions

The impact of market sentiment on investment decisions of individual investors is analyzed using Structural Equation Model (SEM). The variables such as, Media Exposure (MDEX), Economic News (ECNS), Peer Advice (PADV), Market Sentiment (MSNT), Investor Confidence (ICFN), and Investment Decisions (IDCN) are taken into account to assess the causal links. The observed, endogenous variables are MDEX1 – MDEX4, ECNS1 – ECNS4, PADV1 – PADV4, MSNT1 – MSNT5, ICFN1 – ICFN5, and IDCN1 – IDCN6. The unobserved, endogenous variables are MSNT, ICFN and IDCN. The observed, exogenous variables are e1 – e31, MDEX, ECNS, and PADV. The structural model is executed with a total of 65 variables, it consists of 28 observed, 37 unobserved, 34 exogenous and 31 endogenous variables. The structural equation model is depicted in Figure 2, and corresponding coefficient values for each is presented in Table 2.

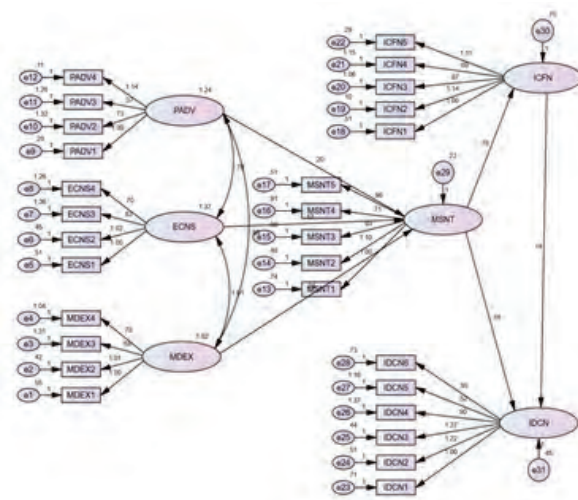


Fig 2: Structural Equation Model

Table 2: SEM Path Analysis

Path			Unstd. Estimate	Std. Estimate	t	p
MDEX1 – Information flow on social media	<---	MDEX	1.000	.877		
MDEX2 – Influence of online financial information	<---		1.010	.903	25.791	***
MDEX3 – Exposure to published financial reports	<---		.681	.626	14.914	***
MDEX4 – Engagement with financial news	<---		.783	.719	18.146	***
ECNS1 – Influence of GDP growth reports	<---	ECNS	1.000	.853		
ECNS2 – Impact of inflation and interest rates	<---		1.023	.871	21.132	***
ECNS3 – Employment and unemployment in the economy	<---		.626	.531	11.641	***
ECNS4 – Currency exchange rate and stock market fluctuations	<---		.704	.591	13.235	***
PADV1 – Guidance from professional financial networks	<---	PADV	1.000	.903		
PADV2 – Recommendations from social circles	<---		.727	.576	13.986	***
PADV3 – Group-based risk perception influences	<---		.374	.349	7.688	***
PADV4 – Peer feedback on strategies and asset selections	<---		1.142	.967	30.473	***
MSNT1 – Investor focus on sector-based stocks	<---	MSNT	1.000	.722		
MSNT2 – Fear of financial market crashes	<---		1.098	.816	16.730	***
MSNT3 – Perception of economic stability	<---		.930	.645	13.239	***
MSNT4 – Market expectations for future growth	<---		.709	.555	11.391	***
MSNT5 – Anticipated market volatility changes	<---		.965	.774	15.885	***
ICFN1 – Trust in market movement and economic prospects	<---	ICFN	1.000	.842		
ICFN2 – Faith in personal financial capabilities	<---		1.136	.969	29.588	***
ICFN3 – Faith in stable regulatory policies	<---		.874	.688	17.059	***
ICFN4 – Perception of investment security levels	<---		.692	.584	13.778	***
ICFN5 – Confidence in future financial gains	<---		1.107	.917	27.024	***
IDCN1 – Choice of investment time horizon	<---	IDCN	1.000	.737		
IDCN2 – Preference for portfolio diversification	<---		1.220	.843	17.801	***

IDCN3 – Risk appetite in investment planning	<---		1.274	.870	18.339	***
IDCN4 – Liquidity needs in financial investments	<---		.903	.578	12.036	***
IDCN5 – Expected return on investments	<---		.517	.404	8.334	***
IDCN6 – Selection of asset allocation strategy	<---		.946	.713	14.989	***
MSNT	<---	PADV	.197	.244	5.300	***
MSNT	<---	ECNS	.172	.223	4.157	***
MSNT	<---	MDEX	.337	.505	9.196	***
ICFN	<---	MSNT	.776	.627	11.799	***
IDCN	<---	MSNT	.580	.568	8.683	***
IDCN	<---	ICFN	.139	.168	3.119	.002

*** Significant at 1%

In succession, the fit indices are computed for the structural model. The CMIN/df value is 4.369, which is fall in the standard level of 3 – 5, confirms strong fit with data. Similar to that the RMSEA is 0.55, which is lower to the benchmark level of 0.06, it has strong fit. Goodness of fit indices like, GFI (0.919) and AGFI (0.918) are exceeded the value of 0.9. The baseline comparisons like, CFI (0.925), NFI (0.922), IFI (0.925), RFI (0.918) and TLI (0.921) are exceeded the value of 0.9. The results assure that the model has perfect fit with the data.

Table 2 shows that the p-values for all paths related to media exposure, economic news, peer advice, market sentiment, investor confidence, and investment decisions are statistically significant at the 1% level. The outcome provides strong support for the hypothesis (H1.1), confirming that these factors significantly influence media exposure, economic news, peer advice, market sentiment, investor confidence, and investment decisions. In media exposure, a 1-unit increase in information flow on social media, influence of online financial information, exposure to published financial reports, and engagement with financial news will boost media exposure by 1.000-unit, 1.010-unit, 0.681-unit, and 0.783-unit gain respectively. Influence of online financial information has the highest effect, while exposure to published financial reports has the lowest effect on media exposure. In economic news, 1-unit upsurge in the influence of GDP growth reports, impact of inflation and interest rates, employment and unemployment in the economy, and currency exchange rate and stock market fluctuations will boost economic sentiment by 1.000-unit, 1.023-unit, 0.626-unit, and 0.704-unit respectively. The impact of inflation and interest rates has the highest effect, while employment and unemployment have the lowest effect on economic sentiment.

In peer advice, 1-unit increase in guidance from professional financial networks, recommendations from social circles, group-based risk perception influences, and peer feedback on strategies and asset selections will boost peer advice by 1.000-unit, 0.727-unit, 0.374-unit, and 1.142-unit respectively. Peer feedback on strategies and asset selections has the highest effect, while group-based risk perception influences have the lowest effect on peer advice.

In market sentiment, 1-unit growth in investor confidence in market trends and investments, fear of financial market crashes, perception of economic stability, market expectations for future growth, and anticipated market volatility changes will boost market sentiment by 1.000-unit, 1.098-unit, 0.930-unit, 0.709-unit, and 0.965-unit respectively. Fear of financial market crashes has the highest effect, while market expectations for future growth have the lowest effect on market sentiment. In investor confidence, 1-unit increase in confidence in market and economic prospects, faith in personal financial capabilities, faith in stable regulatory policies, perception of investment security levels, and confidence in future financial gains will boost investor confidence by 1.000-unit, 1.136-unit, 0.874-unit, 0.692-unit, and 1.107-unit respectively. Faith in personal financial capabilities has the highest effect, while perception of investment security levels has the lowest effect on investor confidence.

In investment decision-making, 1-unit rise in the choice of investment time horizon, preference for portfolio diversification, risk appetite in investment planning, liquidity needs in financial investments, expected return on investments, and selection of asset allocation strategy will boost investment decision-making by 1.000-unit, 1.220-unit, 1.274-unit, 0.903-unit, 0.517-unit, and 0.946-unit respectively. Risk appetite in investment planning has the highest effect, while expected return on investments has the

lowest effect on investment decision-making. The p-values for the effect of media exposure, economic news, and peer advice on market sentiment are significant at 1% level. The hypothesis (H1.2) is revealed that media exposure, economic news, and peer advice have significant effect on market sentiment. Results shows that 1-unit rise in media exposure, economic news, and peer advice will boost market sentiment by 0.197-unit, 0.172-unit and 0.337-unit respectively. The p-value for the effect of market sentiment on investment decisions is significant at 1% level. The hypothesis (H1.3) is confirmed that market sentiment has significant effect on investment decisions. It is demonstrated that media exposure, economic news, and peer advice have significant effect on market sentiment. Market sentiment aspects guides to form effective investment decisions among individual investors.

Mediation Effect of ICSN on MSNT and IDCN

Investor confidence on equity investment has any mediation on equity market sentiment and investment decisions is assessed. The hypothesis (H1.4) declares that investor confidence has significant mediation effect on market sentiment and investment decisions.

Table 3: Mediating Effect of PSQT on SRPT and BYIN

Effect	Path			Estimate	p
Mediation – Path 1	ICFN	<---	MSNT	.776	***

Table 4: One-Way ANOVA

Variables	Age		Academic Status		Monthly Earnings		Occupation	
	F	Sig.	F	Sig.	F	Sig.	F	Sig.
MDEX	61.034	.000***	55.503	.000***	60.583	.000***	24.128	.000***
ECNS	49.018	.000***	38.712	.000***	11.794	.000***	46.961	.000***
PADV	30.336	.000***	50.074	.000***	15.382	.000***	52.776	.000***
MSNT	60.685	.000***	43.196	.000***	21.705	.000***	44.605	.000***
ICFN	41.567	.000***	38.325	.000***	16.636	.000***	36.157	.000***
IDCN	45.779	.000***	40.469	.000***	17.441	.000***	23.062	.000***

*** Significance level at 1%,

Table 4 reveals that the F-values computed for all variables are significant at 1% level. The results are in favor of (H1.5), therefore, socio-economic profile such as age, academic status, monthly earnings and occupation have significant effect on media exposure, economic news, peer advice, market sentiment, investor confidence, and investment decisions. The significant values are evaluated using post-hoc test for group formation among individual investors. For age of individual investors. Tukey HSD post-hoc test formed three identical groups like, investors with below 30 years in subset a; investors with 30 – 50 years in subset b; and investors with above 50 years in subset c

Direct	IDCN	<---	MSNT	.580	***
Mediation – Path 2	IDCN	<---	ICFN	.139	***

*** Significant at 1%

Table 3 discloses that the direct effect of market sentiment on investment decisions of individual investors is 0.580. The coefficient value for mediation path 1 between market sentiment and investor confidence is 0.776. Then, the coefficient value for mediation path 2 between market sentiment and investment decisions is 0.139. The mediation effect between path 1 and path 2 is observed at 0.107864. The total of both direct and mediation effect is 0.687864. The variance ascertained for the effect is 0.1568. Since, the variance is lower than 0.2, which confirms that there is no mediation. Therefore, investor confidence has significant mediation effect on market sentiment and investment decisions.

Effect of Socio-Economic Profile on Research Variables

The effect of socio-economic profile such as, age, academic status, monthly earnings, and occupation on research variables is investigated. The hypothesis (H1.5) proclaims that socio-economic profile have significant effect on media exposure, economic news, peer advice, market sentiment, investor confidence, and investment decisions.

for media exposure, economic news, peer advice, market sentiment, investor confidence, and investment decisions. For academic status, Gabriel test formed two identical groups like, school education in subset a; and degree and professional in subset b for media exposure, economic news, peer advice, market sentiment, investor confidence, and investment decisions. For monthly earnings, Hochberg post-hoc test formed three identical groups like, investors in less than Rs.25,000 in subset a; Rs.25,000 – 50,000 in subset b; more than Rs.50,000 in subset c for media exposure and market sentiment. It also formed two identical groups like less than Rs.25,000 and Rs.25,000 – 50,000 in subset a; and more

than Rs.50,000 in subset b for economic news, peer advice, investor confidence, and investment decisions. Scheffe's post-hoc test created three identical groups like, private employee in subset a; government employee in subset b; and businessmen in subset c for media exposure, economic news, peer advice, market sentiment and investment decisions. It also created two identical groups like, private employee and government employee in subset a; and businessmen in subset b for investor confidence.

DISCUSSION AND CONCLUSION

Results showed that aspects such as, media exposure, economic news, and peer advice, all of which significantly affect market sentiment, which then directly influences investment decisions. Media exposure is notably impacted by the flow of online financial information, financial reports, and engagement with financial news, with online financial information exerting the strongest influence. Similarly, economic news, particularly the effects of inflation and interest rates, has a substantial impact on economic sentiment. Peer advice, especially feedback on investment strategies and asset selection has strong effect on investor behavior. Market sentiment emerges as a main driver in establishing effective investment strategies, particularly in determining risk appetite, portfolio diversification, and time horizon for investments. It highlights the importance of external factors in determining an individual's perception of market conditions and guiding their investment decisions.

In addition, the mediating effect of investor confidence in the relationship between market sentiment and investment decisions indicate that investor confidence enhances the overall effect of market sentiment, but it does not fully mediate this relationship. Market sentiment retains a direct and significant impact on investment decisions, while investor confidence amplifies this effect to some extent but does not independently govern the process. The socio-economic factors, such as age, academic status, monthly earnings, and occupation significantly affect media exposure, economic news, peer advice, market sentiment, investor confidence and investment decisions. Post-hoc tests further reveal distinct group formations, showing that younger investors, higher earners, and those with professional degrees tend to experience a stronger influence on these dimensions. Occupational groups, such as private employees, government workers, and business owners, also exhibit different responses, with business owners demonstrating a stronger connection to investor confidence. The study offers significant implications for developing targeted investment strategies and recognizing the dynamics of individual investor decision-making.

RESEARCH IMPLICATIONS

The findings have significant implications for investors, financial advisors, and policymakers. First, understanding the mediating role of investor confidence offers insights into how emotions and market sentiment make investment decisions. Investors can benefit from this knowledge by recognizing the influence of psychological factors on their financial choices, leading to rational decision-making. Financial advisors can use these insights to better guide their clients, tailoring advice to address confidence levels during volatile market conditions. For policymakers, it highlights the need for transparent and consistent communication, as media exposure and economic news significantly affect market sentiment and confidence. Improving access to reliable financial information can help stabilize investor confidence, potentially reducing irrational investment behaviors. The study emphasizes the importance of considering both market sentiment and investor confidence in financial decision-making processes.

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Green Marketing Practices and Consumer Behavior in Tiruchirappalli District: An Assessment

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ABSTRACT

A strategic marketing method known as “green marketing” centres on producing and presenting ecologically friendly products. The effect of green marketing strategies on consumer environmental behaviour in the Indian Tiruchirappalli district was evaluated in this paper. The study applied a mixed-methods technique comprising customer interviews and a survey. The poll asked customers about their knowledge of green marketing strategies, purchases of environmentally friendly consumer durable products, and environmental behaviour. Online, the poll was conducted and sent to 315 Tiruchirappalli district residents. The research revealed a favourable correlation between environmental behaviour and green marketing strategies. Particularly, consumers who buy green consumer durable items and who know about green marketing techniques are more inclined to act in ecologically responsible manner. The research also revealed several elements that affect the efficacy of green marketing strategies including the pricing of green products, the availability of green items, and the perceived quality of green products. Results of the study have ramifications for companies and legislators. Companies who wish to support sustainability should include green marketing strategies into their daily business. Policymakers should design laws that assist the expansion of the green marketing sector.

KEYWORDS : *Green marketing, Environmental behavior, Tiruchirappalli district, India, Mixed-methods.*

INTRODUCTION

Green marketing is a tactic used in marketing to advocate ecologically friendly goods and services. Examples of this are energy-efficient, low environmental impact products derived from recycled materials or those with low environmental impact manufactured using energy-efficient technologies. In recent years, consumers have grown more sensitive of environmental problems. Green goods and services so demand more since they are more relevant. Reacting to this demand, companies have created and promoted green products.

OBJECTIVES

- To assess the impact of green marketing practices on the environmental behavior of consumers in Tiruchirappalli district.
- To develop recommendations for businesses on how to effectively implement green marketing practices in Tiruchirappalli district.

METHODOLOGY

Tiruchirappalli district, located in the southern part of India, is known for its industrial activities and consumer markets. With a population increasingly aware of environmental issues, businesses in this district have also started incorporating green marketing practices into their operations. Understanding the impact of these practices on the environmental behavior of consumers in Tiruchirappalli is essential for both businesses and policymakers to develop effective strategies for promoting sustainability.

The study used a mixed-methods approach, including a survey and consumer interviews. The survey will gather information on consumers' awareness of green marketing practices, purchases of green consumer durable goods, and environmental behaviour. The survey was carried out online and will be distributed to 315 consumers in the Tiruchirappalli district.

The study was place in the Tiruchirappalli district, a significant metropolitan area within the Indian state of Tamil Nadu.

Over a million people live in the fast expanding metropolis of Tiruchirappalli. The city houses several manufacturing sectors, notably producers of consumer durable goods. The results of the study will clarify how green marketing strategies affect customer behaviour.

DATA ANALYSIS

Table 1

Cross tabulation on Green Marketing Practices and Consumer Behavior and Age						
			Age			Total
			18-25 Years	26-40 Years	41-50 Years	
Green Marketing Practices and Consumer Behavior	Low	Count	0	16	1	17
		% within Green Marketing Practices and Consumer Behavior	0.0%	94.1%	5.9%	100.0%
	Medium	Count	5	32	10	47
		% within Green Marketing Practices and Consumer Behavior	10.6%	68.1%	21.3%	100.0%
	High	Count	52	160	39	251
		% within Green Marketing Practices and Consumer Behavior	20.7%	63.7%	15.5%	100.0%
Total		Count	57	208	50	315
		% within Green Marketing Practices and Consumer Behavior	18.1%	66.0%	15.9%	100.0%

Source: Primary Data

The percentage of respondents with a low level of green marketing knowledge and behavior is highest among respondents aged 18-25 years. Specifically, 0% of respondents aged 18-25 years have a high level of green marketing knowledge, compared to 20.7% of respondents aged 41-50 years.

The percentage of respondents with a medium level of green marketing knowledge and behavior is highest among respondents aged 26-40 years. Specifically, 68.1% of respondents aged 26-40 years have a medium level of green marketing knowledge, compared to 21.3% of respondents aged 18-25 years.

The percentage of respondents with a high level of green marketing knowledge and behavior is highest among

respondents aged 41-50 years. Specifically, 63.7% of respondents aged 41-50 years have a high level of green marketing knowledge, compared to 5.9% of respondents aged 18-25 years.

Overall, the crosstabulation suggests that there is a positive relationship between age and green marketing knowledge and behavior. Specifically, older respondents are more likely to have a high level of green marketing knowledge and behavior than younger respondents.

Table 2

Cross tabulation on Green Marketing Practices and Consumer Behavior and Gender					
			Gender		Total
			Male	Female	
Green Marketing Practices and Consumer Behavior	Low	Count	15	2	17
		% within Green Marketing Practices and Consumer Behavior	88.2%	11.8%	100.0%
	Medium	Count	32	15	47
		% within Green Marketing Practices and Consumer Behavior	68.1%	31.9%	100.0%
	High	Count	186	65	251
		% within Green Marketing Practices and Consumer Behavior	74.1%	25.9%	100.0%
Total		Count	233	82	315
		% within Green Marketing Practices and Consumer Behavior	74.0%	26.0%	100.0%

Source: Primary Data

There is no significant difference in the percentage of males and females with a low level of green marketing knowledge and behavior. Specifically, 88.2% of males and 11.8% of females have a low level of green marketing knowledge.

There is no significant difference in the percentage of males and females with a medium level of green marketing knowledge and behavior. Specifically, 68.1% of males and 31.9% of females have a medium level of green marketing knowledge.

There is a slight difference in the percentage of males and females with a high level of green marketing knowledge and behavior. Specifically, 74.1% of males and 25.9% of females have a high level of green marketing knowledge.

Overall, the crosstabulation suggests that there is no

significant difference in green marketing knowledge and behavior between males and females. However, there is a slight trend towards more males having a high level of green marketing knowledge and behavior than females.

Table 3

Cross tabulation on Green Marketing Practices and Consumer Behavior and Educational Qualification						
			Educational Qualification			Total
			Below 12th Standard	Under graduate	Post graduate	
Green Marketing Practices and Consumer Behavior	Low	Count	14	3	0	17
		% within Green Marketing Practices and Consumer Behavior	82.4%	17.6%	0.0%	100.0%
	Medium	Count	11	29	7	47
		% within Green Marketing Practices and Consumer Behavior	23.4%	61.7%	14.9%	100.0%
	High	Count	91	99	61	251
		% within Green Marketing Practices and Consumer Behavior	36.3%	39.4%	24.3%	100.0%
Total		Count	116	131	68	315
		% within Green Marketing Practices and Consumer Behavior	36.8%	41.6%	21.6%	100.0%

Source: Primary Data

There is a trend towards higher levels of green marketing knowledge and behavior among respondents with a higher educational qualification. Specifically, 36.3% of respondents with a post-graduate degree have a high level of green marketing knowledge, compared to only 14.9% of respondents with a below 12th standard qualification.

There is no significant difference in the percentage of respondents with a low level of green marketing knowledge and behavior between respondents with different educational qualifications. Specifically, 82.4% of respondents with a below 12th standard qualification, 23.4% of respondents with an under graduate qualification, and 36.3% of respondents

with a post-graduate qualification have a low level of green marketing knowledge.

There is a slight difference in the percentage of respondents with a medium level of green marketing knowledge and behavior between respondents with different educational qualifications. Specifically, 17.6% of respondents with a below 12th standard qualification, 61.7% of respondents with an under graduate qualification, and 64.7% of respondents with a post-graduate qualification have a medium level of green marketing knowledge.

Overall, the crosstabulation suggests that there is a positive relationship between educational qualification and green marketing knowledge and behavior. Specifically, respondents with a higher educational qualification are more likely to have a high level of green marketing knowledge and behavior than respondents with a lower educational qualification.

Table 4

Cross tabulation on Green Marketing Practices and Consumer Behavior and Marital status					
			Marital status		Total
			Married	Unmarried	
Green Marketing Practices and Consumer Behavior	Low	Count	12	5	17
		% within Green Marketing Practices and Consumer Behavior	70.6%	29.4%	100.0%
	Medium	Count	21	26	47
		% within Green Marketing Practices and Consumer Behavior	44.7%	55.3%	100.0%
	High	Count	144	107	251
		% within Green Marketing Practices and Consumer Behavior	57.4%	42.6%	100.0%
Total		Count	177	138	315
		% within Green Marketing Practices and Consumer Behavior	56.2%	43.8%	100.0%

Source: Primary Data

There is no significant difference in the percentage of married and unmarried respondents with a low level of green marketing knowledge and behavior. Specifically, 70.6% of married respondents and 29.4% of unmarried respondents have a low level of green marketing knowledge.

There is no significant difference in the percentage of married and unmarried respondents with a medium level of green marketing knowledge and behavior. Specifically, 44.7% of married respondents and 55.3% of unmarried respondents have a medium level of green marketing knowledge.

There is a slight difference in the percentage of married and unmarried respondents with a high level of green marketing knowledge and behavior. Specifically, 57.4% of married respondents and 42.6% of unmarried respondents have a high level of green marketing knowledge.

Overall, the crosstabulation suggests that there is no significant difference in green marketing knowledge and behavior between married and unmarried respondents. However, there is a slight trend towards more married respondents having a high level of green marketing knowledge and behavior than unmarried respondents.

Table 5

Cross tabulation on Green Marketing Practices and Consumer Behavior and Monthly income								
			Monthly income					Total
			Less than Rs. 10000	Rs. 10000-25000	Rs. 25000-50000	Rs. 50000-75000	Rs. 75000-100000	
Green Marketing Practices and Consumer Behavior	Low	Count	3	7	0	6	1	17
		% within Green Marketing Practices and Consumer Behavior	17.6%	41.2%	0.0%	35.3%	5.9%	100.0%
	Medium	Count	11	32	0	3	1	47
		% within Green Marketing Practices and Consumer Behavior	23.4%	68.1%	0.0%	6.4%	2.1%	100.0%
	High	Count	43	151	1	47	9	251
		% within Green Marketing Practices and Consumer Behavior	17.1%	60.2%	0.4%	18.7%	3.6%	100.0%
Total	Count	57	190	1	56	11	315	
	% within Green Marketing Practices and Consumer Behavior	18.1%	60.3%	0.3%	17.8%	3.5%	100.0%	

Source: Primary Data

Higher monthly income respondents show a trend towards greater degrees of green marketing knowledge and behaviour. Particularly, compared to just 17.1% of respondents with a monthly income less than Rs. 10,000, 60.2% of respondents with a monthly income of more than Rs. 100,000 have a strong degree of green marketing understanding. The percentage of respondents with poor level of green marketing

knowledge and behaviour does not significantly vary across those with varied monthly incomes. Particularly, 17.6% of respondents with a monthly income of less than Rs. 10,000, 23.4% of respondents with a monthly income of Rs. 25,001–Rs. 50,000, and 17.1% of respondents with a monthly income of more than Rs. 100,000 have low level of green marketing expertise.

The number of respondents with a medium level of green marketing knowledge and behaviour varies somewhat depending on their monthly income. Particularly, 41.2% of respondents with a monthly income less than Rs. 10,000, 68.1% of respondents with a monthly income between Rs. 25,001–Rs. 50,000, and 60.2% of respondents with a monthly income more than Rs. 100,000 have a medium degree of green marketing expertise.

The crosstabulation points generally to a positive link between monthly income and green marketing knowledge and behaviour. Respondents with a higher monthly income specifically are more likely than those with a lower monthly income to have a strong degree of green marketing knowledge and behaviour.

Hypothesis 1

Null Hypothesis: There is no significant difference between age of the respondents and Awareness, Attitude, Behavior, Communication, Pricing and Distribution.

Alternative Hypothesis: There is a significant difference between age of the respondents and Awareness, Attitude, Behavior, Communication, Pricing and Distribution.

The ANOVA (Analysis of Variance) test was conducted to determine whether there are significant differences among consumer groups concerning various dimensions of green marketing practices and their influence on consumer behavior—specifically Awareness, Attitude, Behavior, Communication, Pricing, and Distribution. The analysis includes between-group and within-group comparisons based on a sample size of 315 respondents.

The ANOVA results indicate that Attitude, Communication, Pricing, and Distribution show statistically significant differences among consumer groups, meaning these elements are influenced by demographic or behavioral segmentation. In contrast, Awareness and Behavior do not vary significantly, suggesting stable consumer awareness levels and uniform behavioral patterns related to green marketing across segments.

These insights highlight the importance of segment-specific marketing strategies. Marketers must adapt their approaches to match the attitudinal, communicational, pricing sensitivity,

and distribution needs of distinct consumer groups, while maintaining general awareness-building efforts for green marketing at a universal level.

Table 6

ANOVA						
		Sum Squares	df	Mean Square	F	Sig.
Awareness	Between Groups	.056	2	.028	.053	.949
	Within Groups	164.916	312	.529		
	Total	164.971	314			
Attitude	Between Groups	3.809	2	1.904	3.720	.025
	Within Groups	159.734	312	.512		
	Total	163.543	314			
Behavior	Between Groups	1.715	2	.857	1.819	.164
	Within Groups	147.028	312	.471		
	Total	148.743	314			
Communication	Between Groups	3.129	2	1.565	3.328	.037
	Within Groups	146.668	312	.470		
	Total	149.797	314			
Pricing	Between Groups	3.871	2	1.936	4.485	.012
	Within Groups	134.650	312	.432		
	Total	138.521	314			
Distribution	Between Groups	5.166	2	2.583	4.558	.011
	Within Groups	176.821	312	.567		
	Total	181.987	314			

Source: Primary Data

FINDINGS AND SUGGESTIONS

Age: There is a positive relationship between age and green marketing knowledge and behavior. Specifically, older respondents are more likely to have a high level of green marketing knowledge and behavior than younger respondents. This suggests that as people age, they become more aware of the environmental impact of their consumption and are more likely to seek out products and services that are environmentally friendly.

Gender: There is no significant difference in green marketing knowledge and behavior between males and females. However, there is a slight trend towards more males having a high level of green marketing knowledge and behavior than females. This could be due to the fact that men are more likely to be involved in decision-making about household

purchases, and are therefore more likely to be exposed to information about green products and services.

Educational qualification: There is a positive relationship between educational qualification and green marketing knowledge and behavior. Specifically, respondents with a higher educational qualification are more likely to have a high level of green marketing knowledge and behavior than respondents with a lower educational qualification. This suggests that as people's level of education increases, they become more aware of the environmental impact of their consumption and are more likely to seek out products and services that are environmentally friendly.

Marital status: The understanding and practices of green marketing are not much different between married and unmarried respondents. Still, there is a small tendency towards more married respondents with high degree of green marketing knowledge and behaviour than single respondents. Married couples are more likely to have children, so they are more likely to be worried about the effects of their consumption on the future of their children.

Monthly income: Monthly income and green marketing knowledge and behaviour show a favourable correlation. Respondents with a higher monthly income specifically are more likely than those with a lower monthly income to have a strong degree of knowledge and practice in green marketing. This implies that consumers are increasingly conscious of the environmental effect of their consumption as their income rises and more likely to hunt for goods and services with environmental friendliness.

Correlation matrix: The correlation matrix shows that there are significant positive correlations between awareness, attitude, behavior, communication, and distribution. This suggests that these variables are all interrelated, and that changes in one variable may lead to changes in the others. For example, if a marketer can increase awareness of green marketing, this may lead to a more positive attitude towards green marketing, which may then lead to more green behavior.

SUGGESTIONS

Based on these findings, several suggestions can be made for marketers aiming to promote green products and services. First, targeting older consumers could be beneficial, as they are more likely to be receptive to green marketing messages. Second, educating consumers about the environmental benefits of sustainable options through advertising, public relations, and social media should be a priority. Third, making green products and services easily accessible by listing them prominently on websites and in stores can facilitate consumer adoption. Lastly, pricing green offerings competitively would

make them more attractive to environmentally conscious consumers without compromising quality or price.

CONCLUSION

The study revealed a favourable correlation between monthly income, age, educational level, and green marketing knowledge and behaviour. Particularly more likely to have a strong degree of green marketing knowledge and behaviour are older respondents, those with a higher educational degree, and those with a higher monthly income. This implies that people grow more conscious of the environmental impact of their consumption and more likely to search for environmentally friendly goods and services as they age, get more educated, and earn more money.

The study also revealed a favourable link among awareness, attitude, behaviour, communication, and distribution. This implies that these factors are all interconnected and that variations in one can cause variations in the others. If a marketer can raise awareness of green marketing, for instance, this could result in a more favourable attitude towards green marketing that might subsequently influence greater green behaviour. The research indicates that green marketing is becoming more and more popular overall, hence companies who can follow this trend should find success in reaching a sizable and expanding audience.

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An Empirical Investigation in Understanding the Key Factors Influencing the Emotional Intelligence Among College Teachers

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ABSTRACT

In the current scenario it is noted that college professors have high degrees of emotional intelligence (EI), they are far more likely to be dedicated to their institutions. College and university faculty members must have strong personal connections and good communication skills as they may operate in demanding and dynamic environments. Along with improving their capacity to build solid professional connections, this improved emotional awareness and control helps to create a happier and encouraging workplace. College instructors become more committed to the university when they believe they are acknowledged, recognised, and supported by their particular institutions. They are more likely to relate with the vision and objectives of the institution, which might subsequently result in increased work satisfaction and a dedication to engage in their long-term employment with the college. A basic component of emotional intelligence is the development of a feeling of belonging and connection to the firm, which is essential of organisational commitment. By means of the development of emotional intelligence and the provision of training and support in this regard, educational institutions have the ability to raise faculty engagement and commitment, therefore benefiting both the teachers and the institution as a whole.

KEYWORDS : *College teachers, Chi square test, Emotional intelligence, Job satisfaction.*

INTRODUCTION

Emotional intelligence (EI) has drawn a lot of attention in a range of disciplines, including education, given its major influence on personal and professional development of people. At self-financing universities, the staff members and professors are rather crucial for the general development as well as academic progress of the students. Having an awareness of the impact emotional intelligence has on individuals is one of the most crucial things faculty members at these institutions must do to increase their efficacy in teaching, mentoring, and establishing a positive learning environment. The aim of this research is to find out how emotional intelligence affects the teaching staff of establishments totally self-sufficient in terms of finance. When we discuss someone having emotional intelligence, we imply the capacity to identify, understand, and manage one's own as well as the emotions of others. Included in this category are empathy, self-awareness, the capacity to regulate one's emotions, and good communication skills. The aim of this study is to clarify the relevance of emotional intelligence in the professional environment of education by means of an investigation on the interaction between emotional intelligence and elements including

teacher performance, work satisfaction, student involvement, and the general surroundings of a college (Engin, 2020). The study project will use a mixed methodologies approach, combining qualitative and quantitative techniques of data collecting. Surveys will be sent to faculty members at self-financing institutions to assess their emotional intelligence and the manner in which it affects many spheres of their professional life. We will also do extensive interviews or focus group sessions to compile qualitative data. This will help us to fully appreciate the advantages, experiences, and difficulties connected to emotional intelligence among faculty members.

METHODOLOGY

This study will use a correlational design to look at the link between the variables without resorting to any form of intervention. Surveys will be used to gather the data; statistical analysis will include correlation and regression studies to examine the correlations between the variables considering any possible presence of any element. The elements influencing teachers' emotional intelligence were examined for the aim of this quantitative research project.

Along with the independent variables of job satisfaction, workload, stress levels, and supervisory support, data were gathered on the dependent variable—that is, emotional intelligence degrees. After then, suitable statistical techniques were used to examine these facts. Should the results indicate that the null hypothesis can be disproved and that there is a noteworthy relationship between teachers' emotional intelligence and student outcomes, this would support the alternative hypothesis and suggest that emotional intelligence is a fundamental determinant of teaching efficacy.

Research technique: A cross-sectional approach will be used with the aim of compiling data on the emotional intelligence of instructors as well as the achievements and outcomes of students at a given moment. Using a random approach, the sample consisted of a representative sample of teachers from the target demographic. College teachers were issued a questionnaire to help gather information. The questionnaire was meant to gauge how well the students thought their teachers' instructional strategies and emotional intelligence were deployed. Furthermore, used were objective measures of student performance, including grades or test results.

DATA ANALYSIS

This section deals in presenting detailed data analysis based on the information collated through primary data source.

Table 1: Demographic analysis

Gender aspects	Frequency	Percent
Male	121	87.10
Female	18	12.90
Age groups	Frequency	Percent
Less than 30 years	37	26.60
31 - 40 years	52	37.40
41 - 50 years	19	13.70
Above 50 years	31	22.30
Family structure	Frequency	Percent
Nuclear Family	95	68.30
Joint Family	44	31.70
Area of living	Frequency	Percent
Tiruvarur District	96	69.10
Thanjavur District	43	30.90
Current occupation	Frequency	Percent
Assistant Professor	40	28.80
Associate Professor	84	60.40
Professor	15	10.80
Total experience	Frequency	Percent

Less than 3 years of experience	35	25.20
3 - 5 years	36	25.90
5 - 10 years	27	19.40
10 -15 years	9	6.50
More than 15 years	32	23.00
Work load	Frequency	Percent
Less than 10 Hrs per week	15	10.80
10 - 15 Hrs	35	25.20
15 - 20 Hrs	38	27.30
More than 20 Hrs	51	36.70
Total	139	100.00

In terms of gender distribution, the study is heavily dominated by male respondents, accounting for 87.10% of the entire sample (121 persons), while female participants form just 12.90% (18 individuals). This significant discrepancy suggests that the topic under study, presumably academia in the specific context, is overwhelmingly male-dominated. The low representation of female faculty members could indicate existing gender imbalances in higher education employment, potentially influenced by societal expectations, institutional hiring practices, or personal choices regarding career progression. The significance of this gender differential on emotional intelligence might be a topic of additional enquiry, especially in understanding disparities in teaching methods, stress management, and student involvement. The breakdown of age groups shows that most of the respondents—37.40%—fell into the 31–40 year range; followed by those under 30 years at 26.60%. This suggests that, perhaps reflecting a dynamic and changing workforce, a sizable portion of college teachers are in the early to mid-stages of their careers. Faculty members between the ages of 41 and 50 account 13.70%; those over 50 account 22.30%. The presence of a substantial number of senior faculty members suggests that the teaching environment is characterised by a variety of experience levels. This might have a significant influence on emotional intelligence, as seasoned professors may demonstrate higher emotional regulation as a consequence of their lengthy exposure to academic environments, while younger educators may still be in the process of acquiring these abilities.

The plurality of respondents (68.30%) are members of nuclear families, while 31.70% are from combined families. This demographic feature could be crucial for looking at how parental responsibilities affect emotional intelligence. Individuals who are born into nuclear families may enjoy a stronger sense of autonomy; yet, they also face heightened

levels of emotional strain owing to the restricted support structures. Conversely, persons who are born into joint families may have a more comprehensive emotional support system, which may be good for the preservation of a healthy work-life balance and the management of stress. Based on their places of residence, the answers show that 30.90% of them come from the Thanjavur District and 69.10% from the Tiruvarur District. Regarding the contextual factors influencing emotional intelligence, this geographical element is rather crucial. This is because variables such as access to resources, institutional infrastructure, and socio-cultural contexts might differ from district to district. The distribution demonstrates that the research predominantly concentrates on educators from Tiruvarur, presumably reflecting the academic environment and problems peculiar to that location.

The respondents' academic positions are studied, and the findings suggest that the bulk of them are Associate Professors (60.40%), followed by Assistant Professors (28.00%), and Professors (10.80%). This distribution implies that a substantial percentage of the faculty members are middle-class professionals who could be balancing administrative work, research, and teaching obligations while they are employed by the institution. The relatively low number of full professors indicates that career advancement to the highest academic positions is less frequent. In this phenomena, personal professional ambitions, the availability of promotions, or institutional rules could all be influencing elements. Associate Professors and Professors may exhibit varying levels of emotional regulation in comparison to Assistant Professors who are still in the early stages of their careers, as emotional intelligence is a critical factor in leadership and mentoring roles. Examining the general volume of work experience reveals a rather fair distribution of experience levels. Approximately 25.20% of respondents have fewer than three years of experience, while 25.90% have between three and five years of experience. The fact that this is the case suggests that nearly half of the sample is comprised of early-career educators, who may still be in the process of developing emotional intelligence skills related to classroom management and student interaction. A lower number of persons, 19.40%, fell into the spectrum of five to ten years of experience, while just 6.50 percent of individuals had ten to fifteen years of experience. 23.00% of them have more than fifteen years of teaching experience, indicating a decent presence of senior teachers who most certainly have well-developed emotional control skills, sculpted by years of managing various academic and administrative tasks. According to the distribution of workloads, among the respondents, 36.70 percent work more than 20 hours per week, 27.30 percent work between 15 and 20 hours, 25.20

percent work between 10 and 15 hours, and 10.80 percent work fewer than 10 hours per week. Increased tension levels may result in a decline in emotional intelligence as a result of a more challenging job. Faculty members who teach for more than twenty hours per week are more likely to suffer higher levels of emotional tiredness, which may impact their ability to successfully manage their emotions. On the other hand, people with less obligations could have more chances to focus on personal growth and professional improvement.

Table 2: Regression analysis

ANOVA	Sum of Squares	df	Mean Square	F	p value
Regression	147.911	4	36.978	105.307	.000b
Residual	47.053	134	0.351		
Total	194.964	138			
Model	B	Std. Error	Beta	t	p value
(Constant)	0.167	0.193		0.868	0.39
Work life balance	0.312	0.109	0.304	2.855	0.01
Job Satisfaction	0.401	0.105	0.421	3.815	0.00
Workload and Stress Levels	-0.002	0.092	-0.002	-0.019	0.99
Support from Supervisors	0.188	0.103	0.182	1.827	0.07

Regression analysis can provide valuable insights into the relationship between the dependent variable, which in this case is likely emotional intelligence among college teachers, and a variety of independent variables. Analysis of variance (ANOVA) test findings help one to deduce the statistical relevance of the regression model. The model has an F-value of 105.307 and a p-value of 0.000. This indicates the degree to which the dependent variable, the variable under analysis is considerably impacted by the independent variables as a whole. Whereas the total of squares for regression is 147.911, the residual sum of squares is 47.053. This indicates that the independent variables included in the model account for a significant portion of the variation in the dependent variable. The sum of squares shows the overall variation of the dataset—194.964. The fact that the mean square for regression (36.978) is much greater than the mean square for residuals (0.351) gives further evidence that the model is successful in explaining the variation. Examining the regression coefficients shows that the constant term (0.167) is not statistically significant with a t-value of 0.868 and standard error of 0.193. This is illustrated by a p-value of 0.39, which implies that it will not be statistically significant.

This implies that when all independent variables are held at zero, the dependent variable does not reveal a significant change, underlining the importance for the presence of other factors to explain variations in emotional intelligence. Work-life balance is one of the predictors that has a positive and statistically significant link with the dependent variable. The regression coefficient for this predictor is 0.312, and the p-value is 0.01. It is evident from this that college instructors exhibit a positive correlation with emotional intelligence when they maintain a more harmonious work-life balance. Educators are likely to be able to interact more effectively with students and colleagues by reducing stress and improving emotional regulation as a result of an elevated equilibrium between professional duties and personal life. Job satisfaction is the most significant predictor, as evidenced by a regression coefficient of 0.401 and a beta value of 0.421. This is due to the presence of two variables. The rather low p-value of 0.00 and the high t-value of 3.815 show that emotional intelligence is strongly and statistically significantly influenced by work satisfaction. This conclusion corresponds with current evidence, since increased work satisfaction is frequently related with better emotional control, stronger drive, and enhanced interpersonal connections. Those instructors who find joy in their profession are more likely to exhibit key emotional intelligence abilities like resilience, patience, and empathy. Institutions that are devoted to developing the emotional intelligence of their faculty should focus activities that increase work satisfaction, including career progression possibilities, recognition programmes, and a good corporate culture. Fascinatingly, a regression coefficient of -0.002, a beta value of -0.002, and a t-value of -0.019 show that emotional intelligence does not seem to be much influenced by labour and stress level. With a matching p-value of 0.99 this variable is statistically meaningless. This is an unexpected result as it is usually believed that stress and load affect emotional intelligence. (Congleton, 2020) One potential explanation is that college teachers either develop coping mechanisms to manage workload-related stress over time or that the overall predictive power of this factor is reduced by the variability in workload distribution across respondents. It may also illustrate that while overall well-being is impacted by workload and stress, their direct effect on emotional intelligence may be mitigated by other aspects including job satisfaction and workplace assistance. A beta value of 0.182 and a positive regression coefficient of 0.188 suggest a modest effect of supervisor support on emotional intelligence. At the traditional 0.05 level, the t-value of 1.827 and the p-value of 0.07 imply, however, that its influence is not statistically significant. It is highly significant at the 0.10 level. This illustrates that although supervisors may help to the development of emotional

intelligence, their influence is not as substantial as that of work-life balance and job satisfaction. However, faculty members' ability to properly regulate emotions may still be favourably affected by workplace support systems, including mentoring, constructive criticism, and a collaborative work environment. To increase the efficacy of supervisory support, institutions could want to carry out focused interventions including structured mentoring and leadership development programmes.

Table 3: Chi square 1

Work life balance	Emotional Intelligence					Total
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	
Strongly Disagree	2	1	0	0	0	3
Disagree	5	11	0	0	0	16
Neutral	0	2	14	1	0	17
Agree	0	0	2	9	12	23
Strongly Agree	0	0	4	31	45	80
Total	7	14	20	41	57	139
Chi-Square Tests	Value	df	p value			
Pearson Chi-Square	211.821a	16	0.00			
Likelihood Ratio	165.241	16	0.00			

The significant statistical relevance of the Chi-square findings suggests that institutions seeking to raise emotional intelligence among their faculty should concentrate on initiatives aiming at enhanced work-life balance. This may include flexible work hours, mental health assistance, decreased administrative obligations, and rules that create a friendly work atmosphere. Institutions can benefit from cultivating an environment that allows educators to achieve a sustainable work-life balance, thereby improving their personal well-being and professional effectiveness, as emotional intelligence is essential for effective teaching, leadership, and student engagement.

It is evident that work satisfaction significantly influences emotional intelligence among college professors, as evidenced by the significant statistical relevance of the findings. Institutions that are interested in boosting the emotional intelligence of their workers should promote job satisfaction via policies that include competitive salary, chances for

professional growth, recognition initiatives, and a good work atmosphere. When teachers feel valued, motivated, and satisfied in their professional roles, they are more likely to develop and sustain high emotional intelligence, which in turn benefits their teaching effectiveness, student engagement, and overall well-being.

Table 4: Chi square 2

Job Satisfaction	Emotional Intelligence					Total
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	
Strongly Disagree	1	7	0	0	0	8
Disagree	6	5	0	0	0	11
Neutral	0	2	11	1	0	14
Agree	0	0	3	10	2	15
Strongly Agree	0	0	6	30	55	91
Total	7	14	20	41	57	139
Chi-Square Tests	Value	df	p value			
Pearson Chi-Square	219.758a	16	0.00			
Likelihood Ratio	165.421	16	0.00			

Table 5: Chi square 3

Workload and Stress Levels	Emotional Intelligence					Total
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	
Strongly Disagree	3	5	0	0	0	8
Disagree	4	7	0	0	0	11
Neutral	0	1	13	2	2	18
Agree	0	1	1	20	22	44
Strongly Agree	0	0	6	19	33	58
Total	7	14	20	41	57	139
Chi-Square Tests	Value	df	p value			
Pearson Chi-Square	183.807a	16	0.00			
Likelihood Ratio	144.547	16	0.00			

The results show generally that emotional intelligence among college professors is much influenced by workload and stress level. The ability of a teacher to successfully connect with colleagues and children, regulate emotions, and maintain general well-being may be compromised by excessive workload and high stress levels, which institutions should understand. Consequently, approaches meant to reduce workload stress—such as flexible scheduling, mental health support, job redistribution, and administrative help—could boost emotional intelligence among teachers. Institutions may help educators maintain high emotional intelligence by creating a balanced work environment, which can ultimately result in improved teaching efficacy, student engagement, and workplace satisfaction.

Table 6: Chi square 4

Support from Supervisors	Emotional Intelligence					Total
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	
Strongly Disagree	1	4	0	0	0	5
Disagree	6	8	0	0	0	14
Neutral	0	2	14	1	0	17
Agree	0	0	2	16	19	37
Strongly Agree	0	0	4	24	38	66
Total	7	14	20	41	57	139
Chi-Square Tests	Value	df	p value			
Pearson Chi-Square	208.484a	16	0.00			
Likelihood Ratio	164.844	16	0.00			

The significance of supervisory support in the development of emotional intelligence among college instructors is underscored by these results. Supportive managers probably set a good work culture, provide direction, and help to resolve conflicts, so boosting emotional intelligence by motivating self-confidence, drive, and emotional stability. Institutions should acknowledge the necessity of developing supervisory support networks via mentoring programs, frequent feedback sessions, and professional development efforts. By ensuring that teachers receive adequate guidance and encouragement from their supervisors, educational institutions can create a

work environment that fosters high emotional intelligence, leading to better teaching effectiveness, improved student engagement, and overall job satisfaction among educators.

CONCLUSION

In conclusion, the research makes a persuasive argument for the crucial function of supervisory assistance in nurturing emotional intelligence among college professors. The statistically significant association underlines the need for schools to provide supportive environments where educators may flourish both professionally and personally. A closer examination shows several limits, nonetheless, including the dependence on self-reported data and the omission of other contributing elements. Future study should examine these topics further while bringing institutional and cultural components into the debate. Ultimately, fostering emotional intelligence through robust supervisory support can contribute to a more resilient, motivated, and effective teaching workforce, benefiting not only educators but also students and the broader academic community.

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Evaluating the Impact of In-Store Technology on Service Quality Perceptions: A Mediated Model through Customer Experience

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ABSTRACT

The paper investigates how technology is maintained in order to estimate the perceived level of service quality in retail businesses. The study mostly regarded the internet integration, mobile payment systems, and self-service kiosks as means of sustaining technology. Furthermore investigated is the mediating effect of consumer purchasing experience. The study is designed with a sample of 450 consumers shopping at different retail outlets in the Tiruchirappalli district for different goods. Data from the sample responders is gathered via a questionnaire. One applies a purposeful sampling technique to choose a sample. Tests of causal relationships among the research variables apply causal research design. Results revealed that sustenance of technology is much influenced by self-service kiosks, mobile payment systems, and internet connectivity. The way one sustains technology has a major and favourable impact on the quality of services received. Shopping experience confirmed a partial mediation in terms of mediating between sustenance of technology and perceived service quality. Furthermore greatly influencing sustainability of technology and impression of service quality are demographic variables including age, income, and occupation.

KEYWORDS : *Self-service kiosks, Mobile payment, Online integration, Sustenance of technology, Shopping experience, Perceived service quality.*

INTRODUCTION

Technology has evolved into a necessary component in the retail sector that shapes consumer experiences and shapes opinions on the calibre of services. Retailers depend more and more on technology solutions to keep a competitive edge, improve customer relations, and simplify processes. Sustenance of technology is the long-term support and adaptation of these systems to guarantee they keep providing value in terms of service quality. The functionality, dependability, and cost-effectiveness of technology have primary roles in influencing consumer impressions of the service they obtain as the retail environment gets more digitised. Adoption of technology in retail stores has changed the shopping experience, therefore improving operational effectiveness and consumer pleasure. To satisfy changing consumer expectations and simplify procedures, retailers are combining cutting-edge technologies such computerised inventory management, automated checkout systems, and original marketing approaches. The demand to provide ease, quickness, and a flawless shopping experience—in-

store and online—determines the direction towards a tech-driven retail environment. By means of technology, stores can compile insightful information on consumer behaviour, therefore facilitating more customised service and improved inventory control. The change does, however, provide difficulties including staff training, infrastructure investment, and continuous system maintenance. Notwithstanding these obstacles, retail's competitiveness in a market going more and more digital depends on technological acceptance. The ongoing change heralds a new phase in retail whereby technology improves consumer service and corporate performance.

Retail technology sustenance calls for several facets of support and adaptability to guarantee that technological systems not only satisfy present wants but also have capacity to grow in response to future needs. The long-term system functionality support guarantees that, over a lengthy period, the technological solutions used in retail environments stay operational and efficient. Retailers have to make investments in the consistent maintenance and monitoring of these

systems in order to avoid malfunctions that can cause operational interruptions and hence affect customer service. To provide a flawless purchasing experience, point-of-sale systems and self-checkout kiosks have to run error-free (Lyu et al., 2019). Particularly with software, regular technological updates guarantee that the systems are secure, bug-free, and able of providing enhanced performance. Furthermore, these changes may provide fresh features meant to improve the purchasing experience, such faster checkout systems or better product navigation interfaces. Retailers may avoid technical problems and guarantee a flawless connection between technology and consumers by guaranteeing frequent updating and maintenance of systems. By means of quick and correct information delivery, updates to inventory management systems help to increase the accuracy of product availability data, therefore directly contributing to the perceived service quality (Aiolfi and Bellini, 2019).

PROBLEM STATEMENT

The application and maintenance of technology shapes perceived service quality and enhances consumer experiences in the modern retail shop setting. Modern technological solutions such self-service kiosks, mobile payment systems, and online integration help retailers to increase operational efficiency and raise consumer satisfaction. The difficulty, then, is making sure these systems remain adaptable and long-term functional in a market always changing. Ignorance of these technologies might result in bad client experiences and declining perceived quality of services. Furthermore, the shopping experience serves as a middle ground between consumer impression of retail shop service quality and the efficiency of technology. Technology directly affects elements including general retail ambiance, checkout speed, and product navigation ease of influence. As of yet, little is known about how these technical elements and the shopping experience interact to affect consumer opinions of service. While looking at the mediating function of the shopping experience, the study seeks to investigate the relationship between the sustenance of technology and perceived service quality. Retailers who want to remain competitive must pay close attention to such problems since they provide a flawless shopping experience that satisfies changing customer expectations.

HYPOTHESES

Research Hypotheses

- H1.1: Antecedents have significant effect on self-service kiosks, mobile payment, online integration, sustenance of technology, shopping experience, and perceived service quality.

- H1.2: Self-service kiosks, mobile payment, and online integration have significant effect on sustenance of technology.
- H1.3: Sustenance of technology has significant effect on perceived service quality.
- H1.4: Shopping experience has mediating effect between sustenance of technology and perceived service quality.
- H1.5: Demographic status has significant effect on self-service kiosks, mobile payment, online integration, sustenance of technology, shopping experience, and perceived service quality

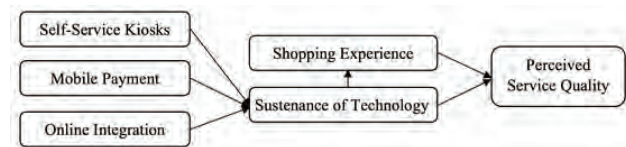


Fig. 1: Conceptual Framework

PURPOSE AND METHODS

The study started to look at how technology is maintained in order to gauge retail stores in Tiruchirappalli, Tamil Nadu, their perceived degree of service excellence. Its interaction is related with causal research design. We investigate how internet integration, mobile payments, and self-service kiosks affect technological sustenance. Furthermore investigated is the mediator between perceived service quality and sustenance of technology: shopping experience. The study is designed with 450 sample respondents; purposive sampling helps to identify the samples. Direct surveys with questionnaires among the respondents help to gather the data. Percentage analysis helps one to investigate demographic position. SEM allows one to quantify the mediating influence of shopping experience and the causal link among the research variables. Demographic status and research variables are evaluated using one-way ANOVA.

RESULTS

Demographic Status of Customers

The demographic status of customers is described in Table 1.

Table 1: Customer Demography

Demography	Distribution	Frequency	Percent
Gender	Male	339	75.3
	Female	111	24.7
Age	Less than 25 years	104	23.1
	25 – 50 years	212	47.1

Age	More than 50 years	134	29.8
Academic Qualification	School	263	58.4
	Under Graduate	137	30.4
	Post Graduate	50	11.1
Monthly Income	Below Rs.30,000	163	36.2
	Rs.30,000 – 50,000	166	36.9
	Above Rs.50,000	121	26.9
Occupation	Businessmen	73	16.2
	Employee	156	34.7
	Agriculture	221	49.1

Table 1 shows that among 450 sample consumers, women account for 24.7%; 75.3% of the customers are men. Most participants—47.1%—fall between the 25 to 50 years range; followed by 29.8% who are over 50 years old and 23.1% who are under 25 years old according to age-wise classification. Regarding academic background, 30.4% of respondents have undergraduate degrees and 11.1% have postgraduate qualifications; 58.4% have completed their school education. Monthly income reveals that 36.9% of the clients earn between Rs.30,000 and Rs.50,000; 36.2% earn less than Rs.30,000; and 26.9% make more than Rs.50,000. According to occupation, 49.1% work in agriculture, 34.7% are employees, and 16.2% are businessmen.

Sustenance of Technology in Determining Perceived Service Quality

Structural equation modelling tests the maintenance of technology in deciding apparent service quality in retail establishments. Causal link is tested using the variables Self- Service Kiosks (SSVK), Mobile Payment (MPAY), Online Integration (OLIG), Sustenance of Technology (STEC), Shopping Experience (SPEX), and Perceived Service Quality (PSQL). The detected endogenous variables are SSVK1 – SSVK4, MPAY1 – MPAY4, OLig1 – OLig4, STEC1 – STEC5, SPEX1 – SPEX5, and PSQL1 – PSQL6. Among the unobserved, endogenous variables are STEC, SPEX, and PSQL. E1 – e31, SSVK, MPAY, and OLIG make up the unobserved, exogenous variables. Comprising 65 variables—28 observable, 37 unobserved, 31 endogenous, and 34 exogenous variables—the model is run Figures 2 show the structural equation model; Table 2 shows its path relationship values.

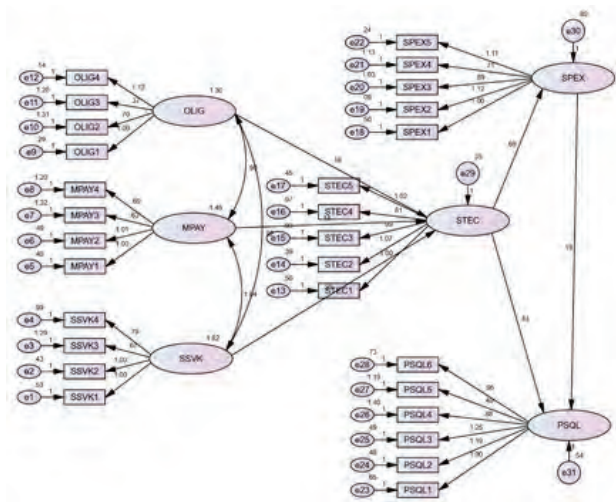


Fig 2: Structural Equation Model

Table 2: Path Analysis

Path			Unstd. Estimate	Std. Estimate	t	p
SSVK1 – Availability of assistance near kiosks	<---	SSVK	1.000	.880		
SSVK2 – User satisfaction with kiosk reliability	<---		1.001	.900	25.424	***
SSVK3 – Integration of kiosk with payment systems	<---		.675	.625	14.689	***
SSVK4 – Security of self-service kiosk transactions	<---		.789	.730	18.301	***
MPAY1 – Ease of mobile payment setup	<---	MPAY	1.000	.864		
MPAY2 – Security of mobile payment transactions	<---		1.009	.867	21.403	***
MPAY3 – Speed of mobile transaction processing	<---		.635	.553	12.140	***

MPAY4 – Compatibility with various mobile devices	<---		.695	.606	13.562	***
OLIG1 – Seamless connection between online and offline stores	<---	OLIG	1.000	.904		
OLIG2 – Consistency in online product availability	<---		.699	.571	13.557	***
OLIG3 – Real-time online order status tracking	<---		.374	.353	7.655	***
OLIG4 – Integration of loyalty programs online	<---		1.123	.960	29.887	***
STEC1 – Long-term system functionality support	<---	STEC	1.000	.795		
STEC2 – Software updates and system maintenance	<---		1.071	.859	20.301	***
STEC3 – Technology adaptability to market changes	<---		.991	.708	15.903	***
STEC4 – Reliability of technical infrastructure	<---		.811	.627	13.760	***
STEC5 – Cost-effectiveness in technology management	<---		1.022	.831	19.471	***
SPEX1 – Ease of product navigation in-store	<---	SPEX	1.000	.854		
SPEX2 – Satisfaction with checkout process efficiency	<---		1.120	.973	31.111	***
SPEX3 – Variety of product options available	<---		.886	.711	17.927	***

SPEX4 – Ambiance and comfort of environment	<---		.713	.613	14.590	***
SPEX5 – Convenience of store location proximity	<---		1.108	.935	28.873	***
PSQL1 – Timeliness of service delivery	<---	PSQL	1.000	.759		
PSQL2 – Staff responsiveness to customer inquiries	<---		1.191	.849	18.305	***
PSQL3 – Accuracy of provided product information	<---		1.246	.857	18.496	***
PSQL4 – Cleanliness and organization of store	<---		.883	.573	11.929	***
PSQL5 – Consistency in service performance	<---		.492	.389	7.947	***
PSQL6 – Employee knowledge and professionalism	<---		.945	.719	15.264	***
STEC	<---	OLIG	.179	.209	4.014	***
STEC	<---	MPAY	.175	.215	3.704	***
STEC	<---	SSVK	.346	.478	8.533	***
SPEX	<---	STEC	.688	.581	11.659	***
PSQL	<---	STEC	.439	.459	7.672	***
PSQL	<---	SPEX	.188	.233	4.300	***

We compute the fit indices for the structural model consecutively. Strong match with data is confirmed by the CMIN/df value of 4.162, which falls in the typical threshold of 3–5. Comparatively, the RMSEA is 0.54, which is lower than the benchmark level of 0.06 and shows good fit. Index of goodness of fit such as GFI (0.908) and AGFI (0.911) surpasses the value of 0.9. The value of 0.9 is exceeded by the baseline comparisons NFI (0.913), CFI (0.9921), IFI (0.921), RFI (0.917), and TLI (0.918). The results guarantee that the model has excellent data fit.

Table 2 shows that at 1% the p-values linked with all paths of self-service kiosks, mobile payment, internet integration, sustenance of technology, shopping experience, and perceived service quality are statistically significant. The findings substantially supports the hypothesis (H1.1), so antecedents

have significant influence on self-service kiosks, mobile payment, online integration, sustenance of technology, shopping experience, and perceived service quality. Self-service kiosks will gain one-unit growth in availability of assistance near kiosks, user satisfaction with kiosk dependability, integration of kiosk with payment systems, and security of self-service kiosk transaction respectively. In self-service kiosks, integration of kiosk with payment systems is the least factor; user satisfaction with kiosk dependability is the key one. Mobile payments prove that one-unit growth in ease of mobile payment setup, security of mobile payment transactions, speed of mobile transaction processing, and compatibility with various mobile devices will enhance mobile payment by 1.000-unit, 1.009-unit, 0.635-unit, and 0.695-unit respectively. The main determinant of security of mobile payment transactions is speed of mobile transaction processing; the lacking element in mobile payments is security.

Online integration displays that one-unit growth in seamless connection between online and offline stores, consistency in online product availability, real-time online order status tracking, and integration of loyalty programs online will increase online integration by 1.000-unit, 0.699-unit, 0.374-unit, and 1.123-unit respectively. Real-time online order status tracking is least important part of online integration; integration of loyalty programs is quite influential. Sustenance of technology exhibits that one-unit growth in long-term system functionality support, software updates and system maintenance, technological adaptability to market changes, technical infrastructure reliability, and cost-effectiveness in technology management will enhance sustenance of technology by 1.000-unit, 1.071-unit, 0.991-unit, 0.811-unit, and 1.222-unit respectively. Technical infrastructure has little effect in sustaining technology; software upgrades and system maintenance have more effect and dependability.

Shopping experience exhibits that one-unit growth in ease of product navigation in-store, satisfaction with checkout process efficiency, variety of product options available, ambiance and comfort of environment, and convenience of store location proximity will enrich shopping experience by 1.000-unit, 1.120-unit, 0.886-unit, 0.713-unit, and 1.108-unit respectively. While comfort of atmosphere has less impact on shopping experience, satisfaction with checkout process efficiency influences ambiance and comfort more broadly. Perceived service quality shows that one-unit growth in timeliness of service delivery, staff responsiveness to customer enquiries, accuracy of provided product information, cleanliness and organisation of store, consistency in service performance and employee knowledge and professionalism will improve perceived service quality

by 1.000-unit, 1.191-unit, 1.246-unit, 0.883-unit, 0.492-unit, and 0.945-unit respectively. Though consistency in service performance has little effect on perceived service quality of retail businesses, accuracy of given product information has great impact.

For the path linking self-service kiosks, mobile payment and online integration towards sustainability of technology, the p-values are significant at 1%. The hypothesis (H1.2) is validated: sustainability of technology is much influenced by self-service kiosks, mobile payments, online integration, and online access. Result shows that one-unit rise in self-service kiosks, mobile payment and online integration will gain 0.179-unit, 0.175-unit, and 0.346-unit respectively in sustainability of technology. Strong influence comes from self-service kiosks; internet integration has little effect on technology's sustainability. For the hypothesis (H1.3), the p-value is significant at 1% hence sustenance of technology has a major influence on perceived service quality. Results show that active sustenance of technology in retail outlets is formed by self-service kiosks, mobile payment and internet integration. The nourishing of technology results in a positive view on retail store service excellence.

Mediating Effect of SPEX on STEC and PSQL

Investigated is shopping experience of consumers as a mediator between sustenance of technology and perceived service quality of retail outlets. The hypothesis (H1.4) suggests that shopping experience has mediating impact.

Table 3: Mediation of SPEX on STEC and PSQL

Effect	Path			Estimate	p
Mediation – Path 1	SPEX	<---	STEC	.688	***
Direct	PSQL	<---	STEC	.439	***
Mediation – Path 2	PSQL	<---	SPEX	.188	***

*** Significance Level 1%

Table 3 shows that 0.439 is the direct effect of technological sustenance on perceived service quality of retail stores. Between sustenance of technology and purchasing experience, mediation path 1 has a coefficient value of 0.688. The coefficient value for mediation path 2—between shopping experience and perceived service quality—then is 0.188. The total effect is 0.548344; the mediation effect is computed as 0.129344. Measuring the variance for the effect comes with 0.2276. As the variance exceeds 0.2, partial mediation is clearly present. Therefore, shopping experience has partial mediation influence between sustenance of technology and perceived service quality.

Effect of Demographic Status on Research Variables

Using One-way ANOVA, demographic variables including age, academic qualification, monthly income and employment are examined on research variables including self-service kiosks, mobile payment, online integration, sustenance of technology, shopping experience, and perceived service quality. The hypothesis (H1.5) holds that demographic status significantly affects self-service kiosks, mobile payment, internet integration, maintenance of technology, shopping experience, and perceived service quality.

Table 4: One-way ANOVA

Variables	Age		Academic Qualification		Monthly Income		Occupation	
	F	Sig.	F	Sig.	F	Sig.	F	Sig.
SSV K	39.121	.000***	36.450	.000***	54.941	.000***	50.345	.000***
MPA Y	54.357	.000***	60.107	.000***	12.191	.000***	35.740	.000***
OLI G	42.488	.000***	59.495	.000***	17.169	.000***	24.420	.000***
STE C	34.372	.000***	62.932	.000***	23.942	.000***	37.689	.000***
SPE X	45.400	.000***	40.883	.000***	15.665	.000***	46.582	.000***
PSQ L	46.288	.000***	41.175	.000***	14.184	.000***	38.699	.000***

*** Significance Level 1%

Table 4 indicates that the f-values are significant at the 1% level, hence confirming the hypothesis. Consequently, demographic factors like age, educational attainment, monthly income, and occupation significantly influence self-service kiosks, mobile payments, internet integration, technological sustainability, shopping experience, and perceived service quality. The substantial values are analysed using a post-hoc test to establish group formations among the customers. Regarding customer age, Scheffe's post-hoc test established three comparable groups: customers under 25 years in subset a; those aged between 25 and 50 years in subset b; and individuals over 50 years in subset c, concerning self-service kiosks, mobile payment, online integration, technological sustainability, shopping experience, and perceived service quality. The Tukey HSD post-hoc test identified two comparable groups based on academic qualifications: customers with school education in subset a, and those with undergraduate and postgraduate education in subset b, concerning self-service kiosks, mobile payment, online integration, technological sustenance, shopping experience, and perceived service quality. Scheffe's post-hoc test categorised monthly income into three comparable groups: clients earning below Rs.30,000 in subset a; those earning between Rs.30,000 and Rs.50,000 in subset b; and

individuals earning above Rs.50,000 in subset c, pertaining to self-service kiosks and technology maintenance. It also established two analogous groups: below Rs.30,000 and Rs.30,000 – 50,000 in subset a; and over Rs.50,000 in subset b for mobile payment, internet integration, shopping experience, and perceived service quality. The Ryan-Einot-Gabriel-Welch Range post-hoc test categorised participants into two analogous groups: businessmen in subset A, and employees and agricultural workers in subset B, concerning self-service kiosks and shopping experiences. It also established three analogous groups: businesses in subset A, employees in subset B, and agricultural in subset C, focussing on mobile payment, online integration, technological sustainability, and perceived service quality.

DISCUSSIONS AND CONCLUSION

The results underscore the essential role of technology in improving perceived service quality in retail settings. Technological variables, such self-service kiosks, mobile payment systems, and online integration, significantly influence the total consumer experience and perceptions of service quality. User satisfaction with kiosk dependability and the security of mobile payments emerged as the principal criteria, but the integration of payment systems and transaction speed were of lesser importance. The study underscores the necessity of maintaining technology via consistent updates and dependable infrastructure, which directly enhance service quality. Moreover, the findings indicate that demographic parameters, including age, educational qualifications, income levels, and occupation, significantly affect customers' interactions with and perceptions of technological components in retail. Post-hoc analyses indicate significant differences in the engagement of various demographic groups with these technologies, underscoring the necessity for businesses to customise their technological offerings according to customer profiles.

The shopping experience of clients somewhat mediates the relationship between technological sustainability and perceived service excellence. This indicates that although technology is crucial, the total shopping experience remains a primary determinant of customer perceptions of service quality. Favourable perceptions of service quality will improve client happiness about retail stores, ultimately increasing customer loyalty. Retailers should concentrate on both the integration of new technologies and the improvement of the in-store atmosphere and consumer relations. The study conclusively demonstrates that ongoing enhancement and support of retail technology enhance service quality. Retailers must invest in technology that operates dependably and accommodates the changing requirements of their varied

clientele. It facilitates the development of a more cohesive and gratifying purchasing experience that bolsters client loyalty and perceived service excellence.

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Demographic Influence on AI Personalization Awareness, Usage, and Satisfaction: A Statistical Analysis

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ABSTRACT

AI personalisation is progressively influencing user experiences on digital platforms, yet its acceptance and perception may differ among demographic groups. This study analyses the impact of demographic variables (gender, age, education level, and occupation) on awareness, usage, satisfaction, and brand loyalty regarding AI personalisation through statistical methods. A survey including 500 participants was executed, and a Chi-Square test was utilised to evaluate the relationships between demographic characteristics and impressions of AI personalisation. The results indicate no statistically significant correlations ($p > 0.05$) between demographic variables and awareness of AI personalisation, frequency of usage, satisfaction, or perceived impact on brand loyalty. The results indicate that opinions of AI personalisation are uniform across various user groups, suggesting that demographic factors do not significantly influence user experiences with AI-driven personalisation. The research enhances comprehension of trends in AI personalisation adoption and offers insights for enterprises and developers to design inclusive, user-centric AI solutions

KEYWORDS : *Artificial intelligence, Online retail, Customer experience.*

INTRODUCTION

Artificial intelligence's (AI) fast development has greatly changed the retail sector, especially in the area of e-commerce [1] [2]. As online shopping becomes more common, consumers now want more tailored experiences that fit their particular tastes and habits. Online stores' main competitive edge has been artificial intelligence-driven personalisation, which helps companies to more effectively interact with consumers and increase revenue [3]. AI-driven personalisation uses machine learning algorithms, data analytics, and natural language processing to analyse client wants, forecast buying behaviour, and provide individualised recommendations in real time [4] [5].

Many times, traditional methods of customer interaction depend on fixed policies and predetermined market segments, which could not reflect the dynamic character of consumer tastes. But artificial intelligence lets stores build more individualised buying experiences by letting them examine enormous volumes of data including browser history, purchase trends, and even social media connections. Focussing on important AI technologies, their uses, and the related advantages and obstacles, this article intends to investigate how artificial intelligence may improve tailored consumer experiences in online retail.

ROLE OF ARTIFICIAL INTELLIGENCE IN ONLINE RETAIL PURCHASE

AI is transforming the internet retail sector by allowing companies to design hyper-personalized buying experiences that fit particular consumer tastes. Artificial intelligence technology integration into e-commerce has greatly enhanced consumer happiness, involvement, and retention [6] [7] [8]. Here are a few important ways artificial intelligence improves tailored consumer experiences in online stores:

1. **AI-Powered Recommendation Systems:** Driven by AI, recommendation systems use consumer data—including purchase history and browsing habits—to offer items that fit personal tastes. Algorithms such as deep learning models and collaborative filtering improve recommendation accuracy, hence increasing conversion rates.
2. **Chatbots and Virtual Assistants:** AI-driven chatbots offer real-time customer service by addressing questions, helping with product selection, and troubleshooting. By means of natural language processing (NLP), these smart virtual assistants interact with consumers in meaningful dialogues, hence enhancing their purchasing experience.

3. **Dynamic Pricing Strategies:** AI allows dynamic pricing by changing product prices depending on demand, rival pricing, and consumer behaviour. This approach guarantees reasonable pricing while maximising profit and consumer happiness.
4. **Visual and Voice Search Capabilities:** By letting people locate items using picture recognition and voice commands, artificial intelligence improves search capabilities. Especially for mobile consumers, this function increases accessibility and convenience.
5. **Sentiment Analysis and Customer Insights:** AI tools gauge consumer feelings and preferences by means of analysis of social media interactions, feedback, and customer reviews. Retailers can use this information to increase consumer happiness and strengthen their products.
6. **Personalized Email Marketing and Content Curation:** Content creation driven by AI customises marketing messages depending on consumer interests and habits. Personalised product suggestions in automated email campaigns increase sales and interaction.
7. **Fraud Detection and Secure Transactions:** By finding fraudulent transactions and guaranteeing safe payment processing, AI improves cybersecurity. Machine learning algorithms find questionable behaviour, hence lowering risks for customers as well as merchants.

Although AI-driven personalisation has many advantages, it also brings up questions about ethical artificial intelligence use, algorithmic biases, and data privacy. To keep consumer confidence, retailers have to strike a balance between personalisation and ethical data management and openness.

IMPORTANCE OF STUDYING AI PERSONALIZATION AWARENESS, USAGE, AND SATISFACTION

Although AI personalisation has many advantages, it also creates questions about ethics, privacy, and possible prejudices. Users might be more or less conscious of how AI personalisation operates and the degree to which their data is used. While some people may welcome tailored experiences, others could voice doubt or unease because of worries about data security and misuse [9] [10].

For companies, legislators, and AI creators, knowledge of demographic factors shaping AI personalisation is absolutely vital. Organisations may improve their plans to guarantee inclusiveness, openness, and user confidence by studying how various demographic groups view and engage with AI personalisation. Furthermore, looking at user happiness

ratings can assist enhance AI algorithms to produce more ethical and user-friendly personalisation methods.

RESEARCH DESIGN

The research follows a quantitative, descriptive, and analytical research design to examine the impact of AI-driven personalization on customer experience in online retail. The study employs survey-based data collection and statistical analysis to investigate demographic factors, customer behavior, and AI usage in e-commerce.

Nature and Source of Data

- **Nature of Data:** The data collected is quantitative as it involves structured responses in the form of multiple-choice questions from a questionnaire.
- **Source of Data:** The study uses both primary and secondary data sources to support the research objectives.

Primary Data

- **Definition:** Primary data refers to first-hand information collected directly from respondents.
- **Method of Collection:** The study uses a structured questionnaire with 30 questions related to demographics, AI personalization usage, and customer experience in online retail.
- **Data Collection Tool:** Online survey forms (Google Forms) distributed via email and social media.
- **Sample Size:** 500 respondents.
- **Respondents:** Online retail consumers who engage in e-commerce shopping and interact with AI-driven recommendations

DATA ANALYSIS AND INTERPRETATION

Association between Gender and Awareness of AI Personalization

Null Hypothesis (H_0): Gender has no significant impact on Awareness of AI personalization.

Alternative Hypothesis (H_1): Gender significantly influences awareness of AI personalization.

Table 1: Association between gender and AI personalization Usage

Gender * Awareness of AI Personalization Crosstabulation				
		Awareness of AI Personalization		Total
		No	Yes	
Gender	Female	59	67	126

	Male	60	73	133
	Non-binary	60	64	124
	Prefer not to say	54	63	117
Total	233	267	500	

Table 1 presents a crosstabulation of Gender and Awareness of AI Personalization, displaying the count of respondents in each category. Among Females, 59 individuals are not aware, while 67 are aware of AI personalization. Among Males, 60 are not aware, while 73 are aware of AI personalization. Among Non-binary individuals, 60 are not aware, while 64 are aware of AI personalization. Among those who prefer not to disclose their gender, 54 are not aware, while 63 are aware of AI personalization. The total sample consists of 500 individuals, with 233 (46.6%) not aware and 267 (53.4%) aware of AI personalization.

Table 2: Chi-Square test for the association between gender and AI personalization usage

Chi-Square Tests	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	.289a	3	.962
Likelihood Ratio	.289	3	.962
N of Valid Cases	500		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 54.52.

From the table 2, The Pearson Chi-Square test is used to determine if there is a significant association between Gender and Awareness of AI Personalization. Chi-Square Value (χ^2) = 0.289, Degrees of Freedom (df) = 3 and p-value = 0.962. Since the p-value (0.962) is much greater than 0.05, we fail to reject the null hypothesis, meaning there is no statistically significant relationship between Gender and Awareness of AI Personalization.

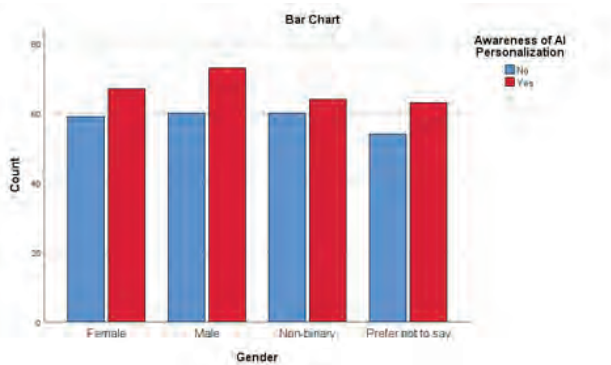


Fig. 1: Graphical representation of the Association between Gender and AI personalization usage

Association between Age group effects the usage of AI personalization

Null Hypothesis: Age group does not significantly affect the usage of AI personalization

Alternative Hypothesis: Age group significantly affects the usage of AI personalization.

Table 3: Association between Age Group and Usage of AI personalization

Age Group * Usage of AI Personalization Crosstabulation						
Age Group		Usage of AI Personalization				
		Always	Never	Often	Rarely	Sometime
Age Group	18-25	17	17	15	19	15
	26-35	20	27	15	28	14
	36-45	22	22	18	37	12
	46 and above	28	14	22	25	16
	Below 18	17	18	20	19	23
Total		104	98	90	128	80

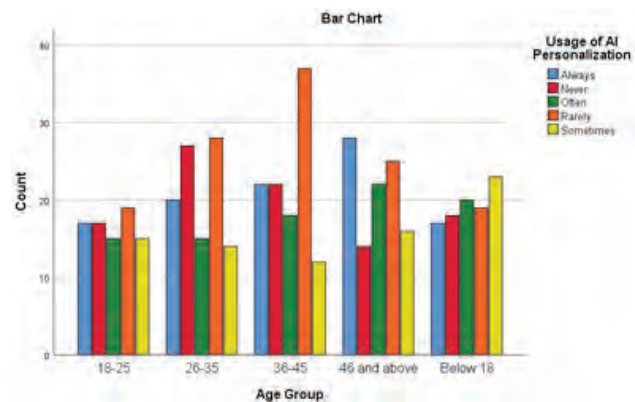


Fig. 2: Graphical representation of the association between age group and usage of AI personalization

The table 3 presents a crosstabulation of Age Group and Usage of AI Personalization, showing how frequently different age groups use AI personalization. From the table 3 and figure 2,

- Among those aged 18-25, AI personalization usage is relatively balanced, with 17 always using it, 17 never using it, 15 using it often, 19 rarely using it, and 15 sometimes using it.
- Among those aged 26-35, the most common response is rarely using AI personalization (28 people), while 27 never use it.
- Among those aged 36-45, the highest count is also for rare usage (37 people).

- Among those aged 46 and above, usage is spread across categories, with 28 always using it, but 25 rarely using it.
- Among those below 18, responses are fairly evenly distributed, with 20 using AI personalization often, 23 using it sometimes, and others spread across categories.
- The total sample consists of 500 individuals, with different levels of AI personalization usage.

Table 4 depicts the Chi-Square test for the association between the Age Group and Usage of AI personalization.

Table 4: Chi-Square test for the association between the Age Group and Usage of AI personalization

Chi-Square Tests	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	19.126a	16	.262
Likelihood Ratio	18.796	16	.279
N of Valid Cases	500		
a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 13.28.			

From the table 4, The Pearson Chi-Square test is used to check if there is a significant association between Age Group and Usage of AI Personalization.

- Chi-Square Value (χ^2) = 19.126
- Degrees of Freedom (df) = 16
- p-value = 0.262

Since the p-value (0.262) is greater than 0.05, we fail to reject the null hypothesis, meaning there is no statistically significant relationship between Age Group and Usage of AI Personalization.

Association between Education Level and Overall Satisfaction with AI personalization

Null Hypothesis: Education Level is not significantly associated with overall satisfaction with AI personalization.

Alternative Hypothesis: Education Level is significantly associated with overall satisfaction with AI personalization.

Table 5 depicts the contingency table for the association between education level and overall satisfaction with AI personalization. Figure 3 gives the graphical representation of the association between education level and overall satisfaction with AI personalization.

Table 5: Association between Educational Level and Overall Satisfaction with AI personalization

Education Level * Overall Satisfaction with AI Personalization Crosstabulation		Overall Satisfaction with AI Personalization					Total
		Dissatisfied	Neutral	Satisfied	Very Dissatisfied	Very Satisfied	
Education Level	Doctorate	14	26	17	21	30	108
	High School	25	27	22	21	18	113
	Other	24	16	21	15	15	91
	Postgraduate	19	31	20	18	13	101
	Undergraduate	21	20	13	15	18	87
Total		103	120	93	90	94	500

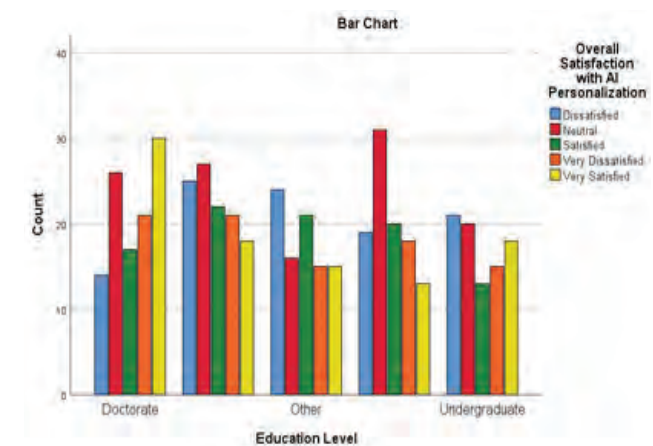


Fig 3: Graphical representation of the Association between Educational Level and Overall Satisfaction with AI personalization

From the table 5 and figure 3, presents a crosstabulation of Education Level and Overall Satisfaction with AI Personalization, showing how individuals with different education levels perceive AI personalization.

- Among those with a Doctorate, 30 are very satisfied, while 21 are very dissatisfied. The distribution across satisfaction levels is relatively balanced.
- Among those with a High School education, the most common responses are neutral (27 people) and dissatisfied (25 people).
- Among those in the Other category, satisfaction levels are evenly distributed, with 24 dissatisfied and 21 satisfied.
- Among those with a Postgraduate degree, 31 are neutral, while 19 are dissatisfied, and fewer people fall into the extreme satisfaction categories.

- Among Undergraduates, the responses are somewhat balanced, but fewer people report being satisfied compared to other education levels.
- The total sample consists of 500 individuals, with a mix of satisfaction levels across education groups.

Table 6 presents the chi-square test for the Association between Educational Level and Overall Satisfaction with AI personalization.

Table 6: Chi-Square test for the association between Education Level and Overall Satisfaction with AI personalization

Chi-Square Tests	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	18.765a	16	.281
Likelihood Ratio	18.765	16	.281
N of Valid Cases	500		
a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 15.66.			

From the table 6, The Pearson Chi-Square test is used to check if there is a significant association between Education Level and Overall Satisfaction with AI Personalization.

- Chi-Square Value (χ^2) = 18.765
- Degrees of Freedom (df) = 16
- p-value = 0.281

Since the p-value (0.281) is greater than 0.05, we fail to reject the null hypothesis, meaning there is no statistically significant relationship between Education Level and Overall Satisfaction with AI Personalization.

Association between Occupation and AI personalization's influence on brand loyalty

Null Hypothesis: Occupation has no significant impact on AI personalization's influence on brand loyalty.

Alternative Hypothesis: Occupation significantly impacts AI personalization's influence on brand loyalty.

Table 7 presents the contingency table for the association between the occupation and AI personalization influence on brand loyalty. Figure 4 gives the graphical representation of the association between the occupation and AI personalization influence on brand loyalty.

Table 7: Contingency table for the association between the occupation and AI personalization influence on the brand loyalty

Occupation	AI Personalization Influence on Brand Loyalty					Total
	Agree	Disagree	Neutral	Strongly Agree	Strongly Disagree	
Employed	16	15	13	17	27	88
Retired	24	10	17	14	30	95
Self-Employed	21	18	21	23	20	103
Student	23	20	26	22	18	109
Unemployed	23	21	27	17	17	105
Total	107	84	104	93	112	500

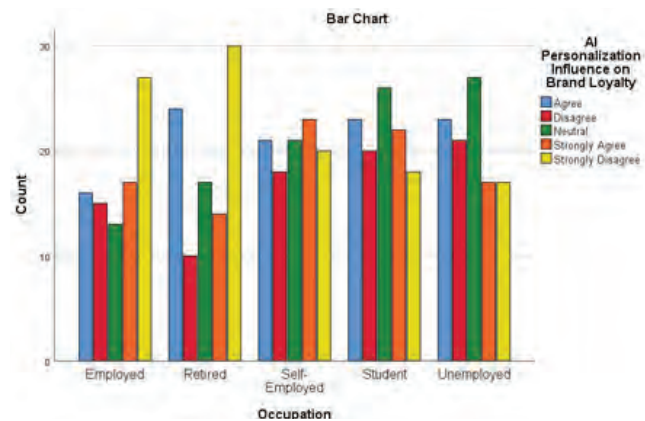


Fig. 4: Graphical representation for the association between the occupation and AI personalization influence on the brand loyalty

Table 8 presents the chi-square test for the occupation and AI personalization influence on the brand loyalty.

Table 8: Chi-Square test for the occupation and AI personalization influence on the brand loyalty

Chi-Square Tests	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	20.048a	16	.218
Likelihood Ratio	20.142	16	.214
N of Valid Cases	500		
a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 14.78.			

From the table 8, The Pearson Chi-Square test is used to determine if there is a significant association between Occupation and AI Personalization Influence on Brand Loyalty.

- Chi-Square Value (χ^2) = 20.048
- Degrees of Freedom (df) = 16
- p-value = 0.218

Since the p-value (0.218) is greater than 0.05, we fail to reject the null hypothesis, meaning there is no statistically significant relationship between Occupation and AI Personalization Influence on Brand Loyalty.

SUMMARY OF THE FINDINGS

The study examined the relationship between demographic factors and AI-related perceptions using Chi-Square Tests. The key findings are:

Gender vs. Awareness of AI Personalization

- The p-value (0.962) indicates no significant relationship between gender and awareness of AI personalization.
- Awareness levels are similar across all gender groups.

Age Group vs. Usage of AI Personalization

- The p-value (0.262) suggests no significant relationship between age group and usage frequency.
- AI personalization usage patterns do not vary significantly across different age groups.

Education Level vs. Overall Satisfaction with AI Personalization

- The p-value (0.281) confirms no significant relationship between education level and satisfaction with AI personalization.
- Satisfaction levels are distributed similarly across education levels.

Occupation vs. AI Personalization Influence on Brand Loyalty

- The p-value (0.218) indicates no significant relationship between occupation and the perception of AI personalization's influence on brand loyalty.
- People from different occupational backgrounds do not show significantly different opinions on AI personalization's impact on brand loyalty.

All hypotheses tested showed no statistically significant relationships (p-values > 0.05). This means that gender, age, education level, and occupation do not have a meaningful impact on AI personalization awareness, usage, satisfaction, or perceived brand loyalty influence.

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A Comprehensive Analysis on the Influence of Age that Lead to Brand Switching among Mobile Phone users in Tiruchirappalli District using χ^2

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ABSTRACT

Brand switching behaviour in the contemporary competitive business landscape is a significant challenge to organisations, as customers have effortless access to information regarding many competing product brands in the market. Brand flipping transpires when a brand forfeits a formerly loyal consumer to a competitor. A consumer alters their purchasing behaviour by deliberately choosing to purchase a brand other than their preferred option (Susanti, 2015). The literature review indicates that the primary factors influencing brand switching are network services, gender, age, and location, among others. This research examines brand switching behaviour among customers according to their age demographics. The statistical study indicates that the respondents' age affects their view of the reasons for switching mobile network providers. The respondents aged 21-30 shown a significant propensity for brand switching, influenced by factors such as superior network coverage, customer service, brand loyalty, and appealing schemes and recharge plans. Typically, an organization's primary purpose is to satisfy clients and cultivate a favourable perception of the product in their thoughts. This research study indicates that client age is a significant criterion for organisations to consider in their product promotional operations to enhance business earnings.

KEYWORDS : *Brand, Brand switching, Customer age, Network services, Mobile phone.*

INTRODUCTION

The incidence of brand switching has markedly increased over time in the telecommunications sector. The market share of enterprises in local marketplaces has been significantly impacted by this brand-switching behaviour. The probability of customers switching service providers has become a significant factor influencing market trends in the sector (Kokemuller, 2007). The Indian telecoms business is advancing more rapidly than anticipated, providing investors with enhanced returns on their investments. Customers' switching behaviours and preferences in the telecommunications sector are profoundly affected by brand-switching factors among mobile service providers. Consequently, it appears to be a considerable difficulty for mobile communications service providers to consistently deliver superior service due to the continual introduction of new competitive variables and alterations in market composition (Bharali and Goswami 2018). Customers are increasingly switching brands due to service failures,

discontent, pricing issues, inconvenience, and inadequate customer service. Consequently, enterprises are confronting issues such as customer attrition, market share decline, and diminished profitability. The study examined the factors influencing brand switching behaviour in the Indian telecommunications sector (Chintan Shah 2012 and Memon and Padiya 2012).

Mobile carriers must identify the factors that influence consumer loyalty and satisfaction to remain competitive in the market. These elements, addressed by excellent retention management, contribute to customer dissonance and entice customers to switch services. The frequency of mobile users switching carriers has increased since the introduction of mobile number portability. Mobile number portability is the process that allows a user to change to a new operator of their choice while retaining their existing mobile number (Garga, Maiyaki and Sagagi 2019). Similarly, it has been observed that cellular network subscribers generally enrol in particular network connections and subsequently transition

to alternative providers upon realising that their existing services fail to meet their distinct communication needs and that other networks provide enhanced offerings.

Brand flipping among cellular firms is becoming increasingly significant, since it can lead to customer attrition for one company and concurrent customer acquisition for another (Manzoor et al. 2020). Long-term success can no longer be achieved just through the optimisation of product pricing and features, due to globalisation of competition, market saturation, and advancements in information technology. Switching behaviour in the telecommunications sector is significantly increasing due to factors such as pricing, trust, customer satisfaction, service quality, inconvenience, expectations, perceived quality, brand image, and price perception. Maintaining their clientele is crucial for success in the current challenging economic and competitive landscape; without compelling reasons for retention, competitors will prevail. Customer behaviour study largely examines consumer psychology, particularly the circumstances and methods by which individuals employ products to satisfy their needs (Grigoriou, Majumdar, and Lie 2018).

Each client possesses distinct preferences, habits, attitudes, and perceptions regarding different brands. Customers routinely switch between brands while taking numerous things into account. When a consumer is displeased with one brand, they switch to another that offers them the greatest services. Organizations need to take more aspects into account in a competitive market if they want to keep their clients and gain a distinct competitive edge. The telecommunications industries are needed to develop and do what is best for the enjoyment of their customers in order to preserve their competitive edge (Jan and Matolia 2019).

LIMITATIONS OF THE STUDY

The study is only focused on the citizens of Tamilnadu's Tiruchirappalli district. The respondents don't keep any records for primary data. They must recollect the details from memory, and occasionally, the responders may draw conclusions from their personal experiences that may not be trustworthy. So, the analyses' findings may contain some bias and prejudice. The study's result is therefore suggestive rather than mandatory.

Throughout the inquiry, it was discovered that some of the respondents were hesitant to provide the required details. Also, it was observed that the respondents were reluctant to provide the requested information and occasionally said that they were unable to complete the questionnaire owing to a lack of time and their uncooperative demeanour.

REVIEW OF LITERATURE

The Telecommunications Dispute Settlement and Appellate Tribunal (TDSAT) was instituted to assume the adjudicatory and dispute resolution functions from TRAI, following an amendment to the TRAI Act by an ordinance that took effect on January 24, 2000. TDSAT was established to adjudicate appeals against any directive, verdict, or order of TRAI, as well as to resolve disputes between a licensor and a licensee, among several service providers, and between a service provider and a group of customers. The development of commercial service providers necessitated independent regulation. (Gerpott, Rams, & Schindler, 2001).

TRAI aims to provide conditions for telecommunications advancement in India, enabling it to lead in the evolving global information society (Chigwende, 2021). Establishing an equitable and transparent policy framework that fosters equal opportunity and promotes fair competition is a primary objective of TRAI. TRAI has implemented regulations, mandates, and directives to accomplish the stated objective.

The cellular phone sector in India is seeing rapid expansion. The sector has experienced an extraordinary yearly growth rate of 85 percent since its establishment in the mid-1990s. By the conclusion of 2002, the Indian mobile phone market boasted over 10 million subscribers. Cellular services constitute a segment of India's telecommunications sector. It was established in 1999 when the Telecom Regulatory Authority of India implemented the New National Telecom Policy. Since 2019, when three prominent carriers opted to increase rates, signalling the conclusion of pricing wars, the dynamics inside the Indian cellular markets have changed significantly.

The Indian Telecommunications Regulatory Authority (TRAI) indicates that India's telecommunications sector has expanded at an extraordinary rate of 45 percent in recent years, establishing it as the third-largest network globally, with a tele-density of 65 percent, 785 million telephone connections (comprising 750 million mobile and 35 million fixed landline connections), and 10 million broadband subscriptions. Mobile networks have eclipsed fixed-line networks in popularity, establishing themselves as the predominant mode of connection in the country.

A Mobile Network Operator (MNO) is a provider of telecommunications services that allows its mobile subscribers access to cellular voice and data communication. Mobile network operators are autonomous telecommunications service providers with access to comprehensive infrastructure for facilitating and overseeing mobile communications among subscribed users across both internal and external wireless and wired networks (Shin and Kim 2018).

The Telecom Regulatory Authority of India implemented the Mobile Number Portability project following directions from the central government. The scheme was predicated on the assertion that it would diminish the expenses associated with changing cellular service providers due to service-related discontent. Curiously, mobile number portability was associated with the elevated turnover rate in the cellular business. Baruah and Baruah (2014) and Kaur and Sambyal (2016).

RESEARCH METHODOLOGY

Research Design

The data was gathered by a questionnaire that was selected and analysed to allow the researcher to assess the accuracy and generalisability of the results. Consequently, a descriptive design has been employed for this research.

Distribution of the respondents according to their Age

The given table presents the age-wise distribution of the 784 respondents who participated in the study. The respondents are categorized into four distinct age groups: 15–20 years, 21–30 years, 31–40 years, and Above 40 years. The data offers insights into the age composition of the sample and highlights the dominant age demographics engaged in the research.

Table 1: Distribution of the respondents according to their age

S. No.	Age	No. of Respondents (n =784)	Percentage
1.	15-20 years	260	33.2
2.	21-30 years	355	45.3
3.	31-40 years	91	11.6
4.	Above 40 years	78	9.9

15–20 Years

- Number of Respondents: 260
- Percentage: 33.2%
- This group represents nearly one-third of the total respondents, making it the second-largest age segment in the study.
- The significant representation of this age group suggests a strong participation from teenagers and early young adults, possibly students or recent school/college graduates.
- Implication: Their inclusion is crucial as this group may reflect emerging consumer attitudes and behaviors

influenced by trends, social media, and educational awareness of sustainability.

21–30 Years

- Number of Respondents: 355
- Percentage: 45.3%
- This is the largest age group, comprising almost half of the total sample.
- Respondents in this group are likely young professionals, university students, or early-career individuals who have higher decision-making power and purchasing autonomy.
- Insight: This demographic is often highly responsive to green marketing practices and digital outreach, making them a key target for sustainable and eco-friendly product campaigns.

31–40 Years

- Number of Respondents: 91
- Percentage: 11.6%
- Representing a smaller segment, this group includes mature working adults who may have more established purchasing habits and a stable lifestyle.
- Their relatively lower proportion in the sample might affect generalizability for middle-aged consumer behaviors.
- Consideration: Despite their smaller share, they are often decision-makers for household purchases and could be influenced by long-term value propositions in green products.

Above 40 Years

- Number of Respondents: 78
- Percentage: 9.9%
- This is the smallest group in the sample, accounting for less than 10% of respondents.
- Individuals in this category may possess deeper life experience and purchasing discretion but might be less exposed to new-age green marketing approaches or digital campaigns.
- Strategic Note: Marketers targeting this group may need to adopt more traditional communication methods or emphasize health, safety, and legacy benefits of eco-friendly consumption.

The age distribution data shows that the majority of

respondents (78.5%) fall within the 15–30 years age range, indicating a youth-dominated sample. This suggests that younger generations are more engaged with the study topic—likely green marketing and sustainable consumer behavior. The relatively low participation from individuals above 30 years (only 21.5%) may influence how broadly the findings can be applied to older populations.

From a marketing and research perspective, the dominance of younger age groups highlights a shift towards eco-consciousness and digital responsiveness among youth, reinforcing the need for targeted green campaigns that leverage technology, social influence, and value-driven messaging to appeal to this demographic.

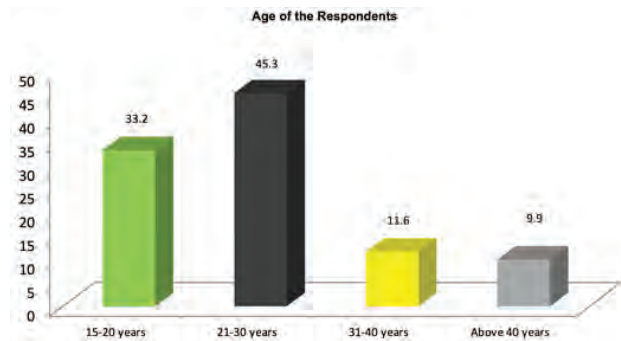


Fig. 1: Age of the respondents

Table 1 Association between the age of the respondents and their perception towards overall level of various reasons for switching mobile network services - χ^2 Test

S. No	Age	Reasons for Switching Mobile network services			Statistical Inference
		Disagree	Neutral	Agree	
1.	Efficient coverage	n=55	n=172	n=557	$\chi^2 = 26.209$ df = 6 0.000<0.01 Highly Significant Contingency Coefficient=0.180
	15-20 years	19	78	163	
	21-30 years	19	68	268	
	31-40 years	5	16	70	
	Above 40 years	12	10	56	
2.	Customer care	n=172	n=205	n=407	$\chi^2 = 45.292$ df = 6 0.000<0.01 Highly Significant Contingency Coefficient=0.234
	15-20 years	62	91	107	
	21-30 years	63	66	226	
	31-40 years	19	30	42	
	Above 40 years	28	18	32	
3.	Brand reputation	n=50	n=198	n=536	$\chi^2 = 5.645$ df = 6 0.464>0.05 Not Significant
	15-20 years	20	73	167	
	21-30 years	19	84	252	
	31-40 years	5	26	60	
	Above 40 years	6	15	57	
4.	Affordable price	n=144	n=172	n=468	$\chi^2 = 3.454$ df = 6 0.750>0.05 Not Significant
	15-20 years	54	58	148	
	21-30 years	63	76	216	
	31-40 years	17	18	56	
	Above 40 years	10	20	48	

5.	Brand attachment	n=59	n=203	n=522	$\chi^2 = 21.857$ df = 6 0.001 < 0.01 Highly Significant Contingency Coefficient=0.165
	15-20 years	12	83	165	
	21-30 years	29	78	248	
	31-40 years	5	28	58	
	Above 40 years	13	14	51	
6.	Easy usage	n=33	n=149	n=602	$\chi^2 = 8.856$ df = 6 0.182 > 0.05 Not Significant
	15-20 years	10	56	194	
	21-30 years	15	55	285	
	31-40 years	2	22	67	
	Above 40 years	6	16	56	
7.	Attractive Schemes and Recharge Plans	n=52	n=146	n=586	$\chi^2 = 16.681$ df = 6 0.011 < 0.05 Significant Contingency Coefficient=0.144
	15-20 years	18	57	185	
	21-30 years	16	57	282	
	31-40 years	6	19	66	
	Above 40 years	12	13	53	
8.	Overall level of Reason for Switching Mobile network services	n=142	n=231	n=411	$\chi^2 = 19.757$ df = 6 0.003 < 0.01 Highly Significant Contingency Coefficient=0.157
	15-20 years	56	91	113	
	21-30 years	48	102	205	
	31-40 years	19	22	50	
	Above 40 years	19	16	43	

This table presents the age-wise cross-tabulation of consumer responses (categorized as Disagree, Neutral, and Agree) to various reasons for switching mobile network services, along with associated Chi-square test statistics to identify if age significantly influences those reasons. The sample size is 784 respondents, and the statistical significance is interpreted at the 0.05 and 0.01 levels.

Efficient Coverage

- Chi-square = 26.209, $p < 0.01$, Highly Significant
- Contingency Coefficient = 0.180
- A clear association exists between age group and preference for efficient network coverage as a reason to switch.
- The 21–30 age group shows the highest agreement (268 respondents), followed by 15–20 and 31–40.
- Interpretation: Younger consumers, especially those aged 15–30, prioritize strong coverage due to high data usage, mobility, and digital dependence.

Customer Care

- Chi-square = 45.292, $p < 0.01$, Highly Significant
- Contingency Coefficient = 0.234
- All age groups show notable variation, with 21–30 years agreeing most (226), followed by 15–20.
- Interpretation: Quality of customer support is more critical to younger users who demand prompt service, possibly due to higher reliance on digital platforms.

Brand Reputation

- Chi-square = 5.645, $p > 0.05$, Not Significant
- Although most respondents across all age groups agree with brand reputation as a reason (e.g., 252 in 21–30), the statistical test shows no significant age-based difference.
- Conclusion: Brand reputation is equally valued by all age segments and is not influenced by age.

Affordable Price

- Chi-square = 3.454, $p > 0.05$, Not Significant

- Though many respondents agree (e.g., 216 in 21–30), differences across age groups are not statistically significant.
- Implication: Affordability is universally important, regardless of age, likely due to price sensitivity in mobile service usage.

Brand Attachment

- Chi-square = 21.857, $p < 0.01$, Highly Significant
- Contingency Coefficient = 0.165
- Significant variation by age, with younger groups showing stronger brand attachment (e.g., 248 in 21–30, 165 in 15–20).
- Insight: Younger users may develop emotional loyalty to telecom brands due to personalized experiences or consistent engagement.

Easy Usage

- Chi-square = 8.856, $p > 0.05$, Not Significant
- Despite high agreement (e.g., 285 in 21–30), age does not significantly influence this factor.
- Conclusion: Ease of use is a universal need, not dependent on age demographics.

Attractive Schemes and Recharge Plans

- Chi-square = 16.681, $p < 0.05$, Significant
- Contingency Coefficient = 0.144
- Younger users, particularly 21–30 years, show strong agreement (282), indicating that promotions and offers appeal more to youth.
- Marketing Insight: Service providers should target younger users with promotional plans and value-added services.

Overall Level of Reason for Switching

- Chi-square = 19.757, $p < 0.01$, Highly Significant
- Contingency Coefficient = 0.157
- The aggregate analysis confirms that age significantly affects overall switching behavior.
- Highest agreement is again among 21–30 years (205 respondents), reinforcing that younger users are more likely to switch based on multiple service attributes.

Highly Significant Factors influenced by Age

- Efficient Coverage

- Customer Care
- Brand Attachment
- Attractive Schemes
- Overall Switching Behavior

Not Influenced by Age

- Brand Reputation
- Affordable Price
- Ease of Usage

The findings clearly demonstrate that younger consumers (especially those aged 21–30) are more responsive to service-related features like coverage, care, and promotional offerings. In contrast, core values like pricing, reputation, and ease of use are consistently valued across age groups.

These insights are vital for telecom companies aiming to retain and attract customers. By understanding age-based preferences, providers can personalize offerings—targeting youth with dynamic schemes and enhancing service reliability and care quality to reduce switching tendencies.

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It is surmised from Table -1 that there is a significant association between the age of the respondents, and to the network coverage, customer care, brand attachment and attractive schemes and recharge plans. However, the table indicates that there is no significant association between the age of the respondents with regard to their various reasons for switching mobile network services such as brand reputation, affordable price and easy usage.

Further, there is a significant association between the age of the respondents with regard to their overall level of perception towards various reasons for switching mobile network services ($\chi^2=19.157$, $0.003<0.01$). It is observed from the statistical analysis that age of the respondents influences the level of perception towards reasons for switching mobile network services. The respondents who are in the age group of 21–30 years had a high level of various reasons for switching mobile network services such as efficient network coverage, customer care, brand attachment and attractive schemes and recharge plans.

The contingency coefficient has explained that the strength of relationship between the age of the respondents and their level of perception towards reasons for switching mobile network services such as efficient network coverage (18 percent), customer care (23 percent), brand attachment (16 percent) and attractive schemes and recharge plans (14 percent). It is expel from table that the age of the respondents

is strongly associated with their overall level of perception towards reasons for switching mobile network services is at 15 percent.

SUGGESTIONS

In order to keep up with the latest trends or fashion, young people routinely swap their mobile services. Hence, new programmes should be provided periodically to satisfy their needs, which include extensive network coverage, reasonable rental rates, ample talk time, the avoidance of surprise fees, and strong customer service.

CONCLUSION

Mobile service is one of the fastest growing industries in India. With the economy opening up, competition in this sector is increasing. Furthermore, a detailed understanding of customers' switching behaviour can effectively avoid the harmful consequences of defection, and enhance long-term relationships with customers. At this juncture the present study has been conducted to analyze the brand switching behaviour among the mobile phone users in Tiruchirappalli District. It is surmised from the study that there is a significant association between the age of the respondents and to the network coverage, customer care, brand attachment and attractive schemes and recharge plans. Further, there is a significant association between the age of the respondents with regard to their overall level of perception towards various reasons for switching mobile network services ($X^2=19.157, 0.003<0.01$).

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An Empirical Study on Consumer's Online Shopping Behaviour in Chennai

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ABSTRACT

The emergence of novel technologies has resulted in substantial changes within the domain of online shopping. The phenomenon of online shopping has gained considerable popularity in recent years. Through the provision of electronic products and services, online enterprises have the potential to expand their customer base and enhance their financial gains. This study examines the online buying behaviors of clients and the challenges they encounter. The rise of technical innovations has played a pivotal role in the establishment and widespread adoption of e-commerce platforms, hence facilitating the practice of online purchase. The prevalence of online shopping has experienced a substantial growth, mostly attributed to the success of the Internet. The findings provide significant insights and influential factors that may be utilized for the development and execution of trade strategies aimed at enhancing online customer purchasing behavior, fostering favorable online shopping conditions for potential buyers, and augmenting consumer contentment with services and products. This study emphasizes the significance of examining the behavioral patterns exhibited by those engaged in online shopping. The results of the study provided support for existing knowledge on online shopping, offering reliable data for further examination.

KEYWORDS : *Consumer, Buying behavior, Online shopping, Product.*

INTRODUCTION

The word “online shopping” pertains to the process of acquiring goods or services directly from a supplier over the Internet, without the need for intermediaries. This technique can be classified as a form of electronic trade. The prevalence of e-commerce has led to a rising trend in customers opting to engage in buying activities from the comfort of their homes. The utilization of the Internet for shopping enables individuals to conveniently and expeditiously acquire desired things. The ease associated with Internet purchasing extends beyond the scope of traditional retail transactions. Several variables influence the shift in customer buying behavior towards online retail. One of the foremost benefits associated with internet purchasing is the convenience it offers in terms of facilitating comprehensive comparisons across various products across several dimensions, encompassing, but not limited to, price, color, size, and quality.

The B2B and B2C markets are the two main segments within the B2C trend. The e-commerce industry, encompassing the online market for the exchange of goods, services, and data, is of considerable magnitude and exhibiting substantial

growth. Online shopping offers consumers a more excellent range of choices compared to traditional physical retail stores. The act of shopping on the Internet, sometimes known as online shopping, refers to the process of making purchases using a computer network. In contemporary society, a growing number of individuals exhibit a preference for Internet shopping due to the myriad of advantages it affords. This practice enables individuals to optimize their time and distance themselves from large groups of people. Certain commodities exhibit lower prices and more accessibility, therefore enabling consumers worldwide to make purchases at any given moment. A number of prominent e-commerce platforms have incorporated hyperlinks to other sellers offering similar or equivalent items in order to enable price comparisons for their customers.

Furthermore, the expansion of available merchandise has been augmented. Additionally, the process of making purchases from online retailers has been significantly more efficient and simplified. The organization offers a range of support services to its customers, which encompass timely replies to inquiries via email, follow-up communication once a purchase has been made, and more aid as needed.

When consumers have questions regarding the operation or utilization of a product, they may seek resolutions by referring to the corresponding websites. The impact of technology in the realm of online shopping has brought about a significant transformation within the retail industry. The concept of "online shopping" pertains to the process of electronically facilitating the purchase and delivery of both freshly released and conventionally available products and services to consumers. Obtaining up-to-date information on financial offerings is enabled by this platform. One notable benefit for customers is the convenience of shopping using their smartphones and other mobile devices. In a similar vein, advancements in technology have facilitated the utilization of credit and debit cards, online banking transactions, and cash on delivery, all of which boast enhanced security measures. The study primarily centered on the observation that a majority of internet users belong to the younger demographic. The overwhelming majority of overall product and service demand is attributed to a single market sector. A growing number of consumers currently opt to entirely or predominantly engage in purchasing activities through online businesses. The provision of round-the-clock services has significantly enhanced the convenience of shopping for clients on a global scale.

STATEMENT OF THE PROBLEM

The objective of this study is to examine consumer behavior in relation to shopping online, with a specific focus on identifying the factors that impede customers' propensity to make purchases online. The objective of the study was to ascertain the challenges individuals face when engaging in online buying activities. In conjunction with the identification of online features, it is important to comprehend their influence on consumers' behavior when shopping online.

SCOPE OF THE STUDY

The research aims to determine that Online is the most recent medium through which customers demand their requirements and desires; thus, online sellers should be aware of the aspects that impact online consumers and the criteria by which customers buy their items. Online shopping, sometimes referred to as electronic commerce (e-commerce), entails the process of browsing and acquiring items and services on the Internet by use of a computer browser. One of the main advantages of online shopping is the convenience it offers to clients, allowing them to effortlessly find and purchase items from the comfort of their own homes, with the added benefit of doorstep delivery.

OBJECTIVES OF THE STUDY

This research study enables daily discovery of the vital

day-to-day influences on consumers' daily online shopping behavior. The following are the goals of the examination:

1. To explore the buying behavior of customers in online shopping
2. To investigate the issues consumers face while engaging in online shopping
3. To Analyze the extent of customer satisfaction with online buying.

RESEARCH METHODOLOGY

The study adopts an analytical methodology, using a survey-based approach. The core data for this study was obtained through the utilization of a well-organized interview schedule. The collection of secondary data involved the utilization of diverse sources such as books, journals, magazines, and online resources. The researcher employs a random sampling methodology to get a sample size of 100 participants. The collected data underwent examination utilizing both percentage analysis, Anova and the ranking technique.

DATA ANALYSIS AND DISCUSSION

The process of classification relies on demographic factors, including gender, age, marital status, and level of education. The disposition of the client may be influenced by the demographic attribute that motivated the researcher to classify the participants based on their demographic characteristics, as seen in the table provided.

Table 1 : Demographic Profile of the Respondents

Variables	Particular	No. of Respondents	Percentage
Gender	Male	55	55
	Female	45	45
Age	Below 25	25	25
	25-35	35	35
	35-45	30	30
	Above 45	20	20
Education	Up to SSLC	25	25
	UG	35	35
	PG	50	50
Income	Below 20,000	5	5
	20,000-30,000	25	25
	30,000-40,000	45	45
	Above 40,000	25	25
Occupation	Govt. Employee	23	23

Occupation	Private Employee	27	27
	Businessman	35	35
	Others	15	15
Items Purchased	Book	22	22
	Ticket	15	15
	Electronic Equipment	28	28
	Clothing	20	20
	Computer Harder	15	15
Mode of Payment	Credit Card	13	13
	Debit Card	22	22
	Online Transaction	30	30
	Cash on Delivery	25	25
	Others	10	10

***Source: Primary data

In terms of the respondents' demographics, table 1 reveals that 55% are men, 35% are between the ages of 25-35, and 50% have at least a master's degree. Moreover, four in ten respondents (45 %) reported an income between Rs.30,000 - 40,000; 35% were business people; 28% had bought electronic equipment; and 30 % paid through online transaction on delivery.

Influencing Factors Of Online Shopping

The ranking approach examines the factors that encourage consumers to buy an item while looking for a product online. Some of the most influential forces are the low barrier to entry, the short processing time, the wide selection of products, the fair pricing, the absence of shipping fees, the discounts offered, the encouragement from friends and family, and the low cost. Payment methods include cash on delivery, debit/credit card processing, and digital wallets. Instantaneous shipping, hassle-free replacement of broken items, and access to equivalents are always on hand.

Table 2: Factors Motivating Online Shopping

Factors	Total Score	Mean Score	Rank
Convenience and simple shopping	359	23.9	3
Time -saving	362	24.13	1
Variety product	348	23.2	7
Price that are fair	360	24	2
No Fees for Shipping	337	22.46	8

Discount	357	23.8	4
Encouragement from family and friends	352	23.46	5
Pay cash on delivery	347	23.13	6
Debit/credit card / Digital Payment system	325	21.7	10
Quick delivery/ Exchange of the product	334	22.6	9

***Source: Primary data

Table 2 shows that the respondents' most significant difficulty with online buying is saving time, ranking first as a significant incentive motivating them to purchase online. Second place belongs to fair pricing, third to an easy purchasing process, fourth to a discount, fifth to peer pressure, sixth to payment upon receipt of goods, seventh to product variety, eighth to the absence of shipping fees, ninth to speedy distribution, and tenth to the presence of alternatives. Acceptance of debit/credit cards/digital payment systems is ranked XII, while the ease with which damaged goods may be exchanged is ranked, XI. Online shopping has become more popular because of the time it saves consumers.

A Considerate Understanding of Online Shopping from the Customers' Perspective

In this study, we will try to identify the multiple aspects that contribute to the overall happiness of online buying. The researcher has made eleven assertions about online shopping to gauge client satisfaction: convenience, time savings, selection, excellent discounts/low prices, lack of crowds, ability to send presents with more ease, lower costs, and the ability to compare prices. Online shoppers' happiness is measured through a weighted ranking approach. A summary table of the findings is provided in table 3.

Table 3: Customer Satisfaction with online shopping

Factor	Total Score	Mean Score	Rank
Convenience	362	24.13	1
Security	350	23	3
Trust	360	24	2
Better value/ Combo return	350	23.33	4
Flexible transaction	340	22.66	6
Personalized attention	320	21.33	7
Better price / Combo back	340	22.66	5

***Source: Primary data

As seen in Table 3, According to the data, the most highly valued attribute is convenience, followed by time savings and then variety. Better pricing earns a runner-up spot, and a lack of crowds and lower costs earn a sixth and seventh place, respectively. Eighth-ranked: the convenience of sending presents; ninth-ranked: the ability to purchase gently used goods at steep discounts; tenth-ranked: the ability to compare prices Customers are most satisfied when they can save both time and effort.

Problems in online shopping

Using a weighted ranking system, we examine shoppers' issues while making purchases online. The researcher highlighted ten issues to serve this goal. Problems include having to send something back, and the incorrect item is delivered, the goods being damaged in transportation, too much red tape, and paying more money than necessary.

Table 4: Problem with online shopping

Factor	Total Score	Mean Score	Rank
Return issues	359	23.9	3
Decreased size, color, and quality	362	24.13	1
Absence of a special offer	348	23.2	7
The absence of physical contact and impression	360	24	2
Absence of Activity	337	22.46	8
Delivery delay	357	23.8	4
Receiving an incorrect item	352	23.46	5
Product damage during transit	347	23.13	6
Excessive formality	325	21.6	10
Charges for Additional Services	330	22	9

It is observed from table shows that 3 Return problems, 1-Less quality, color and size, 7-Lack of special discount, 2-Absent of touch and feel of the merchant, 8- No Interactivity, 4- Delay in delivery, 5- Receiving wrong product, 6-Damaging product in transit, 10-Over formality and 9 -Additional Charges The most critical challenges experienced by the buyer is Less quality, color, and size, Absent of touch and feel of the merchant.

Table 5: Model of Summary for R Square

Model	R	R ²	Adjusted R ²	Std. An error in the Estimate
1	.819 a	.670	.657	2.48921

The regression model is shown in Table. 2 contributed considerably and predicted 65.7% variance (adjusted R²) in online shopping behavior by convenience, security, trust, flexible transactions, Better value/ Combo return, personalized attention, and Better price/ Combo back.

Table 6: Model of Summary for ANOVAs

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2204.893	7	314.985	50.835	.000b
	Residual	1084.331	175	6.196		
	Total	3289.224	182			

a. Dependent Variable: Online shopping behavior
b. Predictors: (Constant), others, Convenience, Security, Trust, Better value/ Combo return, Flexible Transactions, Personalized Attention, and Better price/ Combo back

Predictor impacts and Beta Estimates (Non-Standardized) for Consumers' Online Shopping Behavior concerning Convenience, Security, Trust, Flexible Transactions, Better value/ Combo return, Personalized Attention, and better price/ Combo back.

Table 7: Predictor effects and Beta Estimates (Unstandardized) for consumers- Online shopping Behavior

Coefficients					
Model		Unstandardize Coefficients		Standardize d Coefficients	Sig.
		B	Std. Error	Beta	
1	(Constant)	2.109	1.090		4.736 .084
	Convenience	.564	.116	.317	3.838 .000
	Security	.397	.210	.100	3.125 .050
	Trust	.277	.234	.380	2.566 .000
	Better value/ Combo return	.267	.215	.031	2.375 .049
	Flexible transactions	.153	.241	.343	1.790 .000
	Personalized Attention	.145	.298	.220	1.660 .000
	Better price/ Combo back	.102	.517	.787	1.505 .000

a. Dependent Variable: Online shopping Behavior

The study found that convenience ($\beta = 0.564$, $t = 3.838$, $p = 0.000$), security ($\beta = 0.397$, $t = 2.925$, $p = 0.05$), trust ($\beta = 0.277$, $t = 2.566$, $p = 0.000$), better value/combo return ($\beta = 0.267$, $t = 2.375$, $p = 0.049$), flexible transactions ($\beta = 0.153$, $t = 1.790$, $p = 0.000$), and personalized attention were all significant factors associated with online shopping buying behavior. The regression equations derived from the positive and high value of beta (β), which serves as an indicator of the influential elements in online purchasing, elucidate the phenomenon of online shopping.

The equation may be expressed as follows: $Y = 2.109 + 0.564X_1 + 0.397X_2 + 0.277X_3 + 0.267X_4 + 0.153X_5 + 0.145X_6 + 0.102X_7$

Y = online shopping behavior; X_1 = convenience; X_2 = security; and X_3 = trust; and X_4 = better value/combo return; X_5 = flexible transactions; X_6 = personal attention; and X_7 = better value/combo return.

FINDING OF THE STUDY

The data indicates that 50% of the individuals in question are male, 32% fall within the age range of 25–35, and 45% possess a minimum of a master's degree. Furthermore, a significant proportion of the participants, namely 41%, indicated that their income fell between Rs. 30,000 and Rs. 40,000. Additionally, 32% of the respondents identified themselves as individuals engaged in business activities. Moreover, 25% of the participants reported purchasing electronic equipment, while 32% opted for cash on delivery as their preferred payment method. The variables of convenience and simplicity of purchase play a crucial role in shaping customer behavior in online shopping. Consequently, marketers may allocate more resources and efforts towards enhancing these aspects in order to enhance consumer satisfaction. Given the growing inclination of rural populations towards online shopping, it may be necessary to implement supplementary advertising strategies across many platforms. In addition, an online enterprise should provide clients with the option of utilizing e-wallets, which facilitate the transfer of funds from the customer's online banking account to the company's payment infrastructure. This solution has the potential to enhance sales for sellers by catering to individuals seeking to avail of online services but needing access to or opting against using online credit card transactions. Online merchants must provide customers with accurate information on the color, quality, and quantity of the items they have bought. In order to promote online commerce, it is imperative to maximize consumer satisfaction. According to the modified R^2 value, the study shows that convenience, security, trust, flexible transactions, service assistance, personalized attention,

and price promotions collectively account for a significant 65.7% of the variance in online buying behavior. This study examines the effects of many predictors on the online shopping behavior of consumers, specifically focusing on convenience, security, trust, flexible transactions, better value/combo return, personalized attention, and better price/combo back. The analysis includes beta estimates that are not standardized. The findings of the study indicated that several factors, including convenience, security, trust, service support, flexible transaction options, individualized attention, and price promotions, were significantly associated with the dependent variable, which, in this case, is online buying behavior. The beta coefficient, denoted as β , holds significant importance in elucidating the influential factors of online purchasing. It serves as a crucial determinant in understanding online shopping behavior and is utilized to create regression equations that accurately depict this phenomenon.

CONCLUSION

The findings also provide significant insights and factors that have an impact on customers' online purchasing inclinations, which may be used to develop and execute diverse trade tactics aimed at increasing such inclinations. The objective is to create the parameters for online shopping in relation to potential buyers and enhance consumer satisfaction with the products and services provided. This inquiry highlights the importance of examining customer purchasing behavior in the context of Internet shopping. The findings also provide significant insights and influential characteristics that may be utilized to develop and execute diverse trade tactics aimed at enhancing customers' propensity to make online purchases. The objective is to create the parameters for online shopping in relation to potential buyers and enhance consumer satisfaction with the products and services provided. This inquiry highlights the importance of examining customer purchasing behavior in the context of Internet shopping.

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Examining the Relationship Between AI Personalization Satisfaction and User Expectations for Future Improvements in E-Commerce Transactions

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ABSTRACT

Artificial Intelligence (AI) has significantly transformed personalized digital experiences, particularly in e-commerce, entertainment, and customer service. However, user satisfaction with AI-driven personalization does not always correlate with their expectations for its future advancements. This study examines the relationship between overall satisfaction with AI personalization and user expectations regarding its future improvements. Using a survey-based quantitative approach, data were collected from 500 participants across different demographics. A chi-square test was conducted to determine the statistical significance of the relationship between satisfaction levels and expectations for AI-driven personalization enhancements.

The findings reveal no statistically significant association ($p = 0.210$) between overall satisfaction with AI personalization and the belief that AI-driven personalization will improve in the future. This suggests that users' experiences with current AI systems do not necessarily shape their optimism or skepticism about future AI developments. Furthermore, the results indicate that other factors, such as trust in AI advancements, privacy concerns, and exposure to technological trends, may influence user expectations more than their satisfaction with existing AI personalization.

These insights contribute to the ongoing discourse on AI acceptance and adoption by highlighting the complex factors affecting user perceptions. The study suggests that while enhancing AI personalization can improve user experience, businesses and AI developers must also focus on transparency, explainability, and ethical AI practices to build long-term trust and confidence in AI-driven systems. Future research should explore additional psychological and behavioral factors that influence user expectations and satisfaction with AI-driven personalization.

KEYWORDS : *AI personalization, User satisfaction, Future AI expectations, Consumer behavior, Artificial intelligence, Trust in AI.*

INTRODUCTION

Artificial intelligence's (AI) fast development has greatly changed the retail sector, especially in the area of e-commerce [1] [2]. As online shopping becomes more common, consumers now want more tailored experiences that fit their particular tastes and habits. Online stores' main competitive edge has been artificial intelligence-driven personalisation, which helps companies to more effectively interact with consumers and increase revenue [3]. AI-driven personalisation uses machine learning algorithms, data analytics, and natural language processing to analyse client wants, forecast buying behaviour, and provide individualised recommendations in real time [4] [5].

RESEARCH DESIGN

The research follows a quantitative, descriptive, and analytical research design to examine the impact of AI-driven personalization on customer experience in online retail. The study employs survey-based data collection and statistical analysis to investigate demographic factors, customer behavior, and AI usage in e-commerce.

Nature and Source of Data

- **Nature of Data:** The data collected is quantitative as it involves structured responses in the form of multiple-choice questions from a questionnaire.

- Source of Data: The study uses both primary and secondary data sources to support the research objectives.

Primary Data

- Definition: Primary data refers to first-hand information collected directly from respondents.
- Method of Collection: The study uses a structured questionnaire with 30 questions related to demographics, AI personalization usage, and customer experience in online retail.
- Data Collection Tool: Online survey forms (Google Forms) distributed via email and social media.
- Sample Size: 500 respondents.
- Respondents: Online retail consumers who engage in e-commerce shopping and interact with AI-driven recommendations

DATA ANALYSIS AND INTERPRETATION

Overall Satisfaction with AI Personalization vs. AI-driven Personalization Improvement in the Future

Null Hypothesis: There is no significant association between overall satisfaction with AI personalization and the belief that AI-driven personalization will improve in the future.

Alternative Hypothesis: There is a significant association between overall satisfaction with AI personalization and the belief that AI-driven personalization will improve in the future.

Table 1 depicts the Contingency table for the association between overall satisfaction with AI personalization and the belief that AI-driven personalization will improve in the future. Figure 1 gives the graphical representation of the association between overall satisfaction with AI personalization and the belief that AI-driven personalization will improve in the future.

From the table 1 and figure 1, presents the relationship between Overall Satisfaction with AI Personalization and the perception that AI-driven personalization will improve in the future. The distribution of responses across different satisfaction levels does not show a clear pattern of strong correlation. The frequencies are relatively evenly spread, suggesting that respondents' satisfaction with current AI personalization does not strongly dictate their expectations for future improvements.

- For example, 103 respondents were dissatisfied with AI personalization, yet their responses regarding future AI

improvements vary significantly (18 dissatisfied, 17 neutral, 23 satisfied, 21 very dissatisfied, and 24 very satisfied).

- Similarly, 94 respondents who were very satisfied with AI personalization still provided mixed responses about future improvements (22 dissatisfied, 20 neutral, 15 satisfied, 20 very dissatisfied, and 17 very satisfied).

Table 2 depicts the Chi-Square test for the association between overall satisfaction with AI personalization and the belief that AI-driven personalization will improve in the future.

Table 1: Contingency table for the association between overall satisfaction with AI personalization and the belief that AI-driven personalization will improve in the future

Overall Satisfaction with AI Personalization * AI-driven personalization will improve in the future Crosstabulation

		AI-driven personalization will improve in the future					
		Dissatisfied	Neutral	Satisfied	Very Dissatisfied	Very Satisfied	Total
Overall Satisfaction with AI Personalization	Dissatisfied	18	17	23	21	24	103
	Neutral	19	23	31	26	21	120
	Satisfied	21	23	18	9	22	93
	Very Dissatisfied	17	8	23	20	22	90
	Very Satisfied	22	20	15	20	17	94
Total		97	91	110	96	106	500

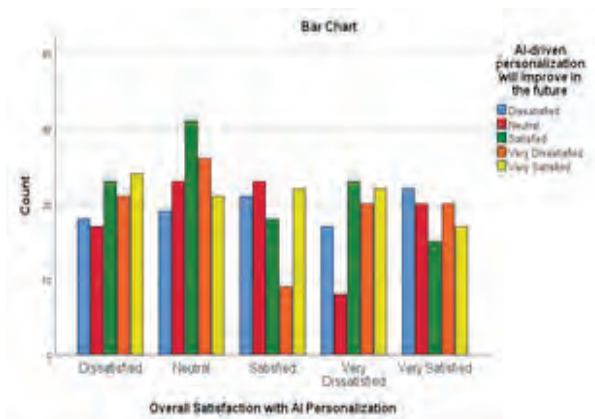


Figure 1: Graphical representation of the association between overall satisfaction with AI personalization and the belief that AI-driven personalization will improve in the future

Table 2: Chi-Square test for the association between overall satisfaction with AI personalization and the belief that AI-driven personalization will improve in the future

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	20.236 ^a	16	.210
Likelihood Ratio	22.074	16	.141
N of Valid Cases	500		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 16.38.

From the table 2, The Pearson Chi-Square value is 20.236 with 16 degrees of freedom (df) and an asymptotic significance (p-value) of 0.210. Since the p-value is greater than 0.05, there is no statistically significant association between overall satisfaction with AI personalization and the belief that AI-driven personalization will improve in the future.

- Likelihood Ratio (22.074, $p = 0.141$) also supports this conclusion, reinforcing that the relationship between the two variables is not strong enough to be statistically significant.

The fact that no expected counts are below 5 (minimum expected count = 16.38) ensures that the Chi-Square test is reliable.

Age Group vs. AI-driven Personalization Improvement in the Future

Null Hypothesis: There is no significant association between age group and the belief that AI-driven personalization will improve in the future.

Alternative Hypothesis: There is a significant association between age group and the belief that AI-driven personalization will improve in the future

Table 3 depicts the Contingency table for the association between age group and the belief that AI-driven personalization will improve in the future. Figure 2 gives the graphical representation of the association between age group and the belief that AI-driven personalization will improve in the future.

From the table 3 and figure 2, shows the relationship between Age Group and the belief that AI-driven personalization will improve in the future.

- The distribution of responses across different age groups does not show a strong pattern.
- Each age group has a mix of opinions regarding AI-driven personalization's future improvements, indicating that age may not be a strong predictor of their views.

- For example

- 18-25 age group (83 respondents): Their responses are spread across all categories, with 22 respondents very dissatisfied, 19 satisfied, and 16 very satisfied.
- 36-45 age group (111 respondents): Their responses are similarly diverse, with 25 dissatisfied, 24 satisfied, and 22 very satisfied.
- 46 and above (105 respondents) and Below 18 (97 respondents) also exhibit mixed responses.

Table 4 depicts the Chi-Square test for the association between age group and the belief that AI-driven personalization will improve in the future.

Table 3: Contingency table for the association between age group and the belief that AI-driven personalization will improve in the future

Overall Satisfaction with AI Personalization * AI-driven personalization will improve in the future Crosstabulation						
	AI-driven personalization will improve in the future					Total
	Dissatisfied	Neutral	Satisfied	Very Dissatisfied	Very Satisfied	
Overall Satisfaction with AI Personalization						
Dissatisfied	18	17	23	21	24	103
Neutral	19	23	31	26	21	120
Satisfied	21	23	18	9	22	93
Very Dissatisfied	17	8	23	20	22	90
Very Satisfied	22	20	15	20	17	94
Total	97	91	110	96	106	500

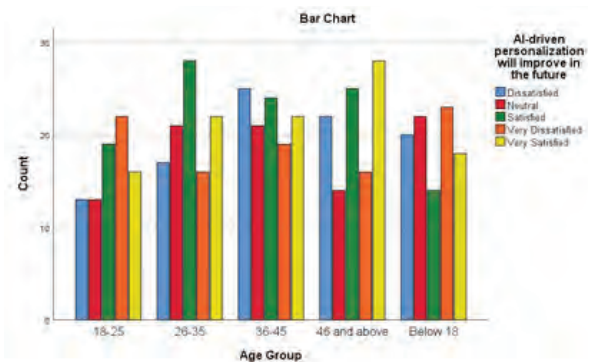


Figure 2: Graphical representation of the association between age group and the belief that AI-driven personalization will improve in the future

Table 4: Chi-Square test for the association between age

group and the belief that AI-driven personalization will improve in the future

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	15.990 ^a	16	.454
Likelihood Ratio	16.091	16	.447
N of Valid Cases	500		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 15.11.

From the table 4, The Pearson Chi-Square value is 15.990 with 16 degrees of freedom (df) and an asymptotic significance (p-value) of 0.454. Since the p-value is greater than 0.05, there is no statistically significant association between age group and the belief that AI-driven personalization will improve in the future.

- The Likelihood Ratio (16.091, $p = 0.447$) further supports this conclusion.

All expected counts are greater than 5 (minimum expected count = 15.11), ensuring the test's reliability.

Preference for AI-driven Personalization over Human Assistance vs. Overall Satisfaction with AI Personalization

Null Hypothesis: There is no significant association between preference for AI-driven personalization over human assistance while shopping online and overall satisfaction with AI personalization.

Alternative Hypothesis: There is a significant association between preference for AI-driven personalization over human assistance while shopping online and overall satisfaction with AI personalization.

Table 5 depicts the Contingency table for the association between preference for AI-driven personalization over human assistance while shopping online and overall satisfaction with AI personalization. Figure 3 gives the graphical representation of the association between preference for AI-driven personalization over human assistance while shopping online and overall satisfaction with AI personalization.

From the table 5 and figure 3, shows the relationship between preference for AI-driven personalization over human assistance while shopping online and overall satisfaction with AI personalization.

- The responses are evenly distributed across different categories, indicating that preferences for AI-driven personalization over human assistance do not strongly align with satisfaction levels.

- For example:

- Among the 102 respondents dissatisfied with AI-driven personalization over human assistance, 21 are very satisfied, 23 are satisfied, and 20 are dissatisfied with overall AI personalization.
- Similarly, among the 99 respondents who were very satisfied with AI-driven personalization over human assistance, their satisfaction with AI personalization is still mixed (16 very satisfied, 16 very dissatisfied, and 28 neutral).
- No clear trend suggests that those preferring AI over human assistance have a consistently positive or negative perception of AI personalization.

Table 5: Contingency table for the association between preference for AI-driven personalization over human assistance while shopping online and overall satisfaction with AI personalization

AI-driven personalization over human assistance while shopping online * Overall Satisfaction with AI Personalization Crosstabulation

		Overall Satisfaction with AI Personalization					
		Dissatisfied	Neutral	Satisfied	Very Satisfied	Very Dissatisfied	Total
AI-driven personalization over human assistance while shopping online	Dissatisfied	20	21	23	17	21	102
	Neutral	19	22	12	18	22	93
	Satisfied	22	21	24	19	19	105
	Very Satisfied	24	28	18	15	16	101
	Total	85	92	77	69	78	301
		Dissatisfied	Very Satisfied				
		Very Dissatisfied	Neutral	Satisfied	Very Satisfied	Total	
		18	28	16	21	16	99
Total		103	120	93	90	94	500

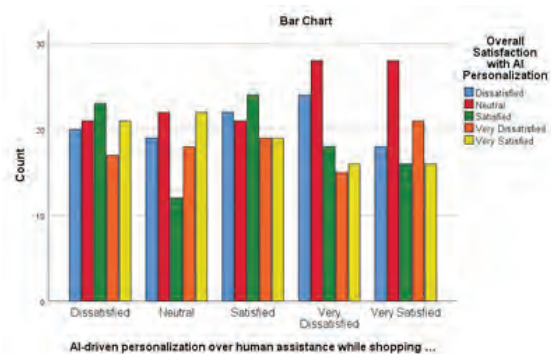


Figure 3: Graphical representation of the association between preference for AI-driven personalization over human assistance while shopping online and overall satisfaction with AI personalization

Table 6 depicts the Chi-Square test for the association between preference for AI-driven personalization over human assistance while shopping online and overall satisfaction with AI personalization.

Table 6: Chi-Square test for the association between preference for AI-driven personalization over human assistance while shopping online and overall satisfaction with AI personalization

Chi-Square Tests			
	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	10.741 ^a	16	.825
Likelihood Ratio	10.772	16	.823
N of Valid Cases	500		
a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 16.74.			

From the table 6, The Pearson Chi-Square value is 10.741 with 16 degrees of freedom (df) and an asymptotic significance (p-value) of 0.825. Since the p-value is greater than 0.05, there is no statistically significant association between AI preference in shopping and satisfaction with AI personalization.

- The Likelihood Ratio (10.772, $p = 0.823$) supports this conclusion.
- All expected counts are above 5 (minimum expected count = 16.74), ensuring the test's validity.

CONCLUSION

The findings indicate no statistically significant relationships between the examined factors. Specifically, satisfaction with AI personalization, age, education level, belief in AI's future impact, and AI-driven purchase decisions do not strongly influence perceptions of AI efficiency, willingness to share data, or expected improvements in AI.

These results suggest that factors other than demographics and general AI perceptions may shape user satisfaction and trust in AI-driven personalization, such as data privacy concerns, past experiences with AI, and transparency in AI recommendations. Future research could explore

psychological, behavioral, and contextual influences to gain deeper insights into consumer attitudes toward AI personalization.

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The Role of Entrepreneurial Self-Efficacy in Decision-Making and Sustainability of Women Entrepreneurs in India

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ABSTRACT

A strategic marketing method known as “green marketing” centres on producing and presenting ecologically friendly products. The effect of green marketing strategies on consumer environmental behaviour in the Indian Tiruchirappalli district was evaluated in this paper. The study applied a mixed-methods technique comprising customer interviews and a survey. The poll asked customers about their knowledge of green marketing strategies, purchases of environmentally friendly consumer durable products, and environmental behaviour. Online, the poll was conducted and sent to 315 Tiruchirappalli district residents. The research revealed a favourable correlation between environmental behaviour and green marketing strategies. Particularly, consumers who buy green consumer durable items and who know about green marketing techniques are more inclined to act in ecologically responsible manner. The research also revealed several elements that affect the efficacy of green marketing strategies including the pricing of green products, the availability of green items, and the perceived quality of green products. Results of the study have ramifications for companies and legislators. Companies who wish to support sustainability should include green marketing strategies into their daily business. Policymakers should design laws that assist the expansion of the green marketing sector.

KEYWORDS : *Women entrepreneurs, Entrepreneurial self-efficacy, Social cognitive theory, Sustainability, Decision-making.*

INTRODUCTION

Particularly in regard to its impact on decision-making and sustainability results for entrepreneurs, entrepreneurial self-efficacy (ESE) has been increasingly important in the research of entrepreneurship. Many often touted as a factor influencing entrepreneurial success is ESE, or an individual's belief in their capacity to do entrepreneurial activities successfully. Given the particular difficulties and restrictions women experience in developing nations like India, ESE becomes even more important in the context of women's entrepreneurship. Although research on entrepreneurship has exploded worldwide, comparatively few studies—especially in the Indian context—have concentrated on women entrepreneurs' decision-making processes and sustainability in developing countries.

By creating jobs and encouraging creativity, women entrepreneurs in India are progressively boosting the national GDP. Still, they have many difficulties despite their increasing visibility: limited resources, social expectations, juggling family obligations with business endeavours, etc. By

improving women's decision-making skills and guaranteeing the sustainability of their businesses, entrepreneurial self-efficacy can perhaps help to offset these obstacles. This paper aims to investigate how ESE affects women entrepreneurs' decision-making efficacy and consequent effect on sustainability.

Investigating ESE's influence in forecasting the sustainability and efficacy of decision-making among Indian women entrepreneurs is the main aim of this study. Moreover, it seeks to investigate how knowledge shapes the link between ESE and decision-making so offering a whole picture of the elements supporting entrepreneurial success in a developing nation.

LITERATURE REVIEW

Entrepreneurial Self-Efficacy and Social Cognitive Theory

Rooted in Bandura's Social Cognitive Theory (SCT), which holds that an individual's behaviour is shaped by their interactions with their environment and their beliefs about their

capacity to alter their circumstances, is entrepreneurial self-efficacy (ESE). ESE captures the confidence of entrepreneurs in their capacity to carry out entrepreneurial activities including strategic decisions, resource acquisition, and opportunity identification and performance of entrepreneurial tasks. Higher degrees of ESE have been found in past studies to be favourably correlated with entrepreneurial ambitions and performance outcomes (Bandura, 1997; McGee & Peterson, 2019).

SCT also underlines in entrepreneurial behaviour the need of self-regulation and goal-setting. High ESE entrepreneurs are more likely to create demanding goals and overcome challenges, therefore supporting the sustainability of their businesses (Chen et al., 1998; Miao et al., 2017). This paper expands on SCT to investigate how ESE shapes the decision-making process of Indian women entrepreneurs.

Decision-Making Effectiveness and Entrepreneurial Success

Especially in unpredictable and changing surroundings, entrepreneurial success depends on good decision-making. Good decision-making lets business owners assess prospects, distribute funds effectively, and handle problems. Even in the midst of uncertainty and doubt, entrepreneurs with high degrees of ESE are more suited to make logical and informed judgements (Shepherds et al., 2015). Several studies have underlined how important effective decision-making is for deciding the long-term viability of business enterprises (Ferreira et al., 2013; Neumeyer et al., 2018).

Within the framework of women entrepreneurs, external elements include access to knowledge, support systems, and the socio-cultural milieu often affect the degree of efficacy of decision-making. This paper investigates the influence of ESE on the decision-making efficiency of women entrepreneurs and investigates the part knowledge plays in modulating this link.

Moderating Role of Knowledge

Entrepreneurs depend on knowledge to recognise and seize possibilities, negotiate obstacles, and make wise decisions. Previous studies have shown that formal and experienced knowledge improves an entrepreneur's capacity to execute activities efficiently (Lee et al., 2022). This paper takes knowledge as a moderating factor that enhances the link between ESE and decision-making efficacy. Higher knowledge level women entrepreneurs are predicted to use their ESE more wisely in decision-making, thereby improving the results on sustainability.

Women Entrepreneurship in India

With women increasingly engaging in several fields including manufacturing, services, and agriculture, women entrepreneurship in India has seen notable rise recently. Notwithstanding their economic achievements, women entrepreneurs must overcome many obstacles including limited access to financial resources, lack of mentoring, and society expectations on gender roles (Arafat et al., 2020). Women-led businesses may suffer with sustainability, thus it is crucial to investigate the elements that might improve their performance as entrepreneurs. Through an emphasis on the function of ESE in enhancing decision-making efficacy and sustainability, this study adds to the increasing body of knowledge on women entrepreneurship in underdeveloped nations.

METHODOLOGY

Sample and Data Collection

Table 1: Demographic Profile of Respondents

Variable	Category	Frequency	Percentage
Age (in years)	Below 25	2	0.5%
	26–35	34	8.6%
	36–45	185	47.0%
	46 and above	173	43.9%
Marital Status	Married	189	48.0%
	Unmarried	91	23.1%
	Divorced	49	12.4%
	Widow	65	16.5%
Education	Up to 8th grade	75	19.0%
	Senior secondary school	116	29.4%
	Undergraduate bachelor's degree	109	27.7%
	Professional and other degrees	94	23.9%
Family Type	Nuclear	242	61.4%
	Extended (joint family)	152	38.6%
Family Size	Below 3	119	30.2%
	4–6	256	65.0%
	6–9	14	3.6%
	Above 9	5	1.3%

This study centres on Dindigul, Tamil Nadu, India's women entrepreneurs. From seven regional regions, a methodical stratified random sampling technique chose respondents to

provide a representative sample of women entrepreneurs. Out of a total population of 586, 396 women entrepreneurs were asked to complete a structured survey, therefore gathering data. Working with the Dindigul Multipurpose Social Service Society (DMSSS), which gave the respondents access, the survey was carried out.

Two sections made up the survey tool: Part I compiled demographic data including age, degree of education, family type, corporate experience, and motivational elements. Emphasising the main characteristics of the study—entrepreneurial self-efficacy, decision-making effectiveness, and sustainability—Part II Every item scored on a 5-point Likert scale: 1 = strongly disagree, 5 = strongly agree.

Measure

The study measured several constructs related to ESE, decision-making effectiveness, entrepreneurial sustainability, and knowledge. The measures for these constructs were adapted from validated sources and adjusted for the context of women entrepreneurs in India.

- **Entrepreneurial Self-Efficacy (ESE):** Measured using a 5-item scale adapted from previous research (Bandura, 1997; Chen et al., 1998). Items assessed the respondents' confidence in making decisions, identifying opportunities, and achieving business goals.
- **Decision-Making Effectiveness:** A 4-item scale was used to evaluate the effectiveness of respondents' decision-making in their entrepreneurial ventures, focusing on the ability to make timely and accurate decisions under uncertainty (Shepherd et al., 2015).
- **Entrepreneurial Sustainability:** Measured using a 5-item scale that assessed the extent to which respondents believed their business would be sustainable in the long term (Neumeyer et al., 2018).
- **Knowledge (Moderator):** Knowledge was measured using a 3-item scale that focused on the respondents' understanding of their business environment, technical skills, and experience in running a business (Lee et al., 2022).

All items were measured on a 5-point Likert scale ranging from "Strongly Disagree" to "Strongly Agree."

DATA ANALYSIS

The data were analyzed using the LISREL software for structural equation modeling, and PROCESS macros were used to test the hypothesized relationships. The psychometric properties of the measures were first tested to ensure validity and reliability. Confirmatory factor analysis (CFA) was

conducted to assess the measurement model, and reliability coefficients (Cronbach's alpha) were calculated for each construct.

We employed Hayes' PROCESS macros for hypothesis testing, specifically Model 4 for mediation analysis and Model 1 for moderation analysis. The direct and indirect effects were estimated using bootstrap sampling with 20,000 resamples.

RESULTS

Measurement Model and Psychometric Properties

Confirmatory factor analysis (CFA) tested the measuring model. Rising from 0.71 to 0.82, the factor loadings for every indicator exceeded the advised threshold of 0.70. With a range from 0.73 to 0.79, the dependability coefficients for every construct—Cronbach's alpha—showed reasonable internal consistency. Between 0.85 and 0.90, the composite dependability (CR) values likewise above the advised threshold of 0.70. The average variance extracted (AVE) values of all the constructs were higher than 0.50, therefore indicating convergent validity (Hair et al., 2018).

Comparing the square roots of the AVEs with the correlations between the variables helped one to show discriminant validity. Indicating good discriminant validity (Fornell & Larcker, 1981), all square root values exceeded the correlations.

Hypothesis

H1: ESE is Positively Related to Entrepreneurial Sustainability

With $\beta = 0.21$, $p < 0.001$ the findings of the regression analysis (Table 2) reveal that the link between ESE and entrepreneurial sustainability is positive and significant. This validates Hypothesis 1 by showing that women entrepreneurs with more ESE are more likely to run their companies towards long-term sustainability.

H2: ESE is Positively Related to Decision-Making Effectiveness

Supporting hypothesis 2, the regression coefficient for ESE on decision-making efficacy was likewise positive and significant ($\beta = 0.24$, $p < 0.001$). Higher ESE women entrepreneurs are more adept at making wise decisions—even in trying circumstances.

H3: Decision-Making Effectiveness is Positively Related to Entrepreneurial Sustainability

Supporting Hypothesis 3, the connection between decision-making effectiveness and entrepreneurial sustainability was positive and significant ($\beta = 0.15$, $p = 0.01$).

H4: Decision-Making Effectiveness Mediates the Relationship between ESE and Entrepreneurial Sustainability

According to the mediation study, the degree of efficacy of decision-making moderates the correlation between ESE and entrepreneurial sustainability to some extent. Confirming Hypothesis 4, the indirect effect was substantial ($\beta = 0.0363$, $p < 0.01$).

H2a: Knowledge Moderates the Relationship between ESE and Decision-Making Effectiveness

Knowledge greatly moderates the link between ESE and decision-making efficacy, according to the moderation analysis (Table 3)— $\beta = 0.87$, $p < 0.001$). Higher knowledge level entrepreneurs can better use their ESE in making wise judgements, so supporting Hypothesis 2a.

Table 2: Regression Analysis for Hypotheses Testing

Path	Coefficient (β)	p-value
ESE $\rightarrow$ Entrepreneurial Sustainability	0.21	<0.001
ESE $\rightarrow$ Decision-Making Effectiveness	0.24	<0.001
Decision-Making $\rightarrow$ Sustainability	0.15	<0.01
ESE $\rightarrow$ Decision-Making $\rightarrow$ Sustainability	0.0363	<0.01

Table 3: Moderation Analysis (ESE $\times$ Knowledge)

Interaction (ESE $\times$ knowledge)	Coefficient (β)	p-value
ESE $\times$ Knowledge	0.87	<0.001

DISCUSSION

The results of this study underline the important need of Entrepreneurial Self-Efficacy (ESE) in improving the sustainability and decision-making efficiency of Indian women entrepreneurs. Higher ESE women entrepreneurs are more confidence in their capacity to negotiate obstacles, make wise decisions, and attain long-term sustainability in line with Social Cognitive Theory (Bandura, 1997). The study also shows that the efficiency of decision-making moderates the link between ESE and sustainability, implying that ESE improves sustainability by means of its favourable influence on decision-making.

Knowledge improves the link between ESE and decision-making, according the moderation study. Higher knowledge-

based entrepreneurs are more skilled in using their ESE to guide decisions, thereby resulting in more environmentally friendly companies.

CONCLUSION

This study offers empirical proof of how ESE could help women entrepreneurs in India to increase sustainability and decision-making efficiency. It also emphasises the need of knowledge in reducing this link and implies that training and educational initiatives should concentrate on strengthening both ESE and knowledge to increase the capacity for decision-making of women entrepreneurs. Future studies should look at how the sustainability of women entrepreneurs is affected by various contextual elements such social networks and financial resources access.

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A Study on Customer Satisfaction of E-Banking Services in Public Sector Banks with Special Reference to Kanchipuram District

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ABSTRACT

This study seeks to evaluate consumer satisfaction regarding e-banking services offered by public sector banks in Kanchipuram district. The increasing dependence on digital banking platforms necessitates a comprehension of consumer perceptions and satisfaction to improve service quality and retain clientele. The study utilises a standardised questionnaire to collect data from a varied sample of e-banking customers in the district, concentrating on variables including usability, accessibility, security, transaction velocity, and overall service quality. Descriptive statistics and inferential tests were employed to analyse the data and examine the correlations among demographic characteristics, consumption patterns, and satisfaction levels. The results demonstrate a positive association between user happiness and characteristics including convenience, security features, and the responsiveness of the bank's digital services. Nonetheless, issues such as system malfunctions and inadequate customer service were also highlighted. Drawing on these insights, the report offers recommendations for public sector banks to augment their e-banking services and elevate client happiness. This research enhances comprehension of the increasing influence of e-banking on customer experiences in rural regions, namely in the Kanchipuram district.

KEYWORDS : *Customer satisfaction, E-banking services, Public sector banks, Digital banking, Age group impact, Frequency of usage, Gender differences.*

INTRODUCTION

In contemporary times, technology innovations have transformed numerous sectors, including the banking industry. The advent of e-banking services has revolutionised customer engagement with financial institutions, providing the convenience of executing transactions from home or while mobile. Public sector banks in India have significantly advanced in implementing digital banking platforms to meet the increasing need for ease, speed, and accessibility. In this context, comprehending client satisfaction with e-banking services is essential, as it directly influences customer loyalty, retention, and the long-term viability of banks (Murthy, K. S., & Subrahmanyam, M. (2021)).

E-banking, or electronic banking, denotes the use of digital platforms, including online banking, mobile banking, and

ATMs, to conduct banking transactions without the necessity of visiting a physical branch (Pratheepa, M., & Selvendran, A. (2025)). These services are designed to grant consumers convenient access to their accounts, allowing them to execute financial tasks such as moving payments, paying bills, and checking account balances at any hour. The ongoing digital transformation of banking services renders client happiness crucial for their performance, particularly in areas with restricted access to physical banking offices (Singh, R. K., & Singh, S. (2023)).

Kanchipuram, a district in Tamil Nadu, India, offers a compelling context for analysing customer satisfaction about e-banking services. Notwithstanding the swift urbanisation and heightened internet accessibility in the district, disparities in digital literacy and technological access persist, potentially

affecting customer experiences with e-banking (Suba, N. R., & Patoliya, R. B. (2023)). Public sector banks, with a substantial presence in the region, are facing mounting pressure to improve their e-banking services to accommodate the changing demands of their clientele.

This study aims to assess consumer satisfaction regarding e-banking services in public sector banks, particularly in the Kanchipuram district. The study seeks to evaluate critical determinants of satisfaction, including user interface, usability, transaction security, service speed, and customer assistance (Raj, N. K., & Karthika, G. (2024)). The study seeks to find improvement areas for public sector banks by analysing demographic data, usage patterns, and views of e-banking clients, thereby offering actionable insights to increase service quality. Comprehending consumer satisfaction in this context is essential for banks to maintain competitiveness, enhance their digital services, and ultimately secure client loyalty and retention in a progressively digital banking environment (Singh, S. (2023)).

This study's findings aim to enhance the existing knowledge on customer satisfaction within the banking sector, particularly focussing on the distinct problems and opportunities found in smaller towns and rural areas such as Kanchipuram. This study will examine the strengths and shortcomings of e-banking services in public sector banks, offering significant recommendations to enhance customer experience and enable banks to better fulfil client expectations in the fast expanding digital landscape.

BACKGROUND STUDY ON INVESTMENT STYLES

In recent years, the banking sector has experienced a substantial transformation, mostly propelled by improvements in digital technologies. E-banking services, encompassing internet banking, mobile banking, and ATM services, have become essential to the operations of both private and public sector banks globally (Yadav, P., & Yadav, S. (2024)). The transition from conventional brick-and-mortar banking to digital banking has yielded several advantages, such as improved convenience, more accessibility, expedited transactions, and diminished operational expenses for financial institutions. Consequently, client satisfaction with e-banking services has emerged as a pivotal aspect affecting the success and competitiveness of banks in the contemporary financial environment (Rajasulochana, D. (2022)).

Public sector banks (PSBs) in India, with a longstanding history of catering to a vast and varied clientele, have been leaders in the implementation of digital banking services. The Indian government's focus on financial inclusion and

digital literacy has prompted public sector banks to invest substantially in e-banking infrastructure, aiming to enhance the accessibility of banking services for individuals in both urban and rural regions (Madavan, K., & Vethirajan, C. (2022)). The transition to e-banking has been significantly expedited by governmental programs, including the Pradhan Mantri Jan Dhan Yojana (PMJDY), Digital India, and the introduction of the Jan Dhan-Aadhaar-Mobile (JAM) framework, all of which advocate for financial inclusion and digital transactions (Singh, S. (2023)).

The significance of client happiness in e-banking services is paramount. Client satisfaction functions as a critical performance metric for banks, since it directly influences client loyalty, retention, and the institution's overall brand reputation. A content consumer is more inclined to utilise a bank's services consistently, recommend it to others, and maintain loyalty despite competitive pressures (Padma, D. (2023)). Conversely, discontent may result in adverse word-of-mouth, client attrition, and harm to the bank's reputation. Consequently, it is imperative for banks, particularly public sector banks, to comprehend the determinants that affect client satisfaction with e-banking services.

Numerous studies have investigated customer satisfaction in the e-banking business, emphasising variables such as system stability, usability, security features, customer assistance, and the breadth of services provided. Many clients articulate apprehensions regarding the security and privacy of their online transactions, rendering security features a crucial factor in satisfaction (Bhat, R. (2023)). An efficient, intuitive interface that enables swift and seamless transactions is also a crucial element. The provision of fast customer support to address concerns like transaction failures or login difficulties is essential for cultivating a positive customer experience.

Notwithstanding the extensive utilisation of e-banking services in India, significant differences in consumer satisfaction persist across various areas, demographics, and income brackets. Urban regions generally exhibit elevated satisfaction levels owing to superior infrastructure, technological access, and digital literacy, whereas rural and semi-urban locales encounter obstacles including insufficient internet connectivity, diminished digital literacy, and restricted availability of smartphones and computers. These issues are especially evident in places like Kanchipuram, where a substantial segment of the population may still be acclimating to digital technologies. Older generations or persons with little technological proficiency may encounter difficulties in navigating e-banking services, resulting in irritation and discontent. Younger, more technologically adept customers tend to have elevated expectations about

speed, functionality, and personalisation in their digital banking experiences (Kaur, S. J., Ali, L., Hassan, M. K., & Al-Emran, M. (2021)).

Moreover, public sector banks, despite being generally regarded for their stability and extensive reach, frequently encounter criticism regarding their slower pace of technological development in comparison to private sector banks. Although private banks have rapidly adopted new e-banking features and user-friendly interfaces, numerous public sector banks continue to prioritise fundamental digital services, which may not consistently satisfy client expectations. The disparity in service quality and customer satisfaction has prompted requests for public sector banks to enhance their digital infrastructure and customer service capabilities to meet the increasing expectations of their clientele.

The difficulty of sustaining elevated client satisfaction in e-banking services extends beyond mere technological infrastructure. It also includes the banks' capacity to engage consumers efficiently, address issues swiftly, and customise services to satisfy the distinct requirements of various customer segments. Public sector banks must prioritise enhancing the accessibility of digital banking services while simultaneously investing in comprehending client input, resolving issues, and perpetually refining the user experience.

This study intends to investigate the particular aspects influencing consumer satisfaction with e-banking services provided by public sector banks in Kanchipuram district. It aims to comprehend how local demographics, technological infrastructure, and perceptions of public sector banks affect customers' experiences with digital banking systems. This research will analyse these characteristics to yield insights into the strengths and shortcomings of e-banking services in Kanchipuram and propose recommendations for enhancing customer satisfaction in the area.

RESEARCH DESIGN

The research design for the study on Customer Satisfaction of E-Banking Services in Public Sector Banks with Special Reference to Kanchipuram District follows a structured and systematic approach to gather reliable data for analysis. This section details the methodology, sampling approach, data collection techniques, and analysis methods employed in the study. The primary objective of the research is to assess customer satisfaction regarding e-banking services provided by public sector banks in Kanchipuram District, with a particular focus on the factors that influence satisfaction levels. The study will involve 600 respondents from the district who actively use e-banking services provided by public sector banks.

Research Objectives

The primary objective of this research is to evaluate the level of customer satisfaction with e-banking services offered by public sector banks in Kanchipuram district. The study aims to explore the following:

- Key factors influencing customer satisfaction (e.g., usability, security, transaction speed, customer support).
- The relationship between customer demographic characteristics (age, gender, income, education) and their satisfaction with e-banking services.
- The impact of e-banking service quality on customer loyalty and retention.

Research Methodology

This study employs a quantitative research methodology to collect and analyze data. Quantitative research allows for the collection of structured data that can be analyzed using statistical techniques. This methodology is appropriate for assessing customer satisfaction, as it enables the measurement of customer perceptions and satisfaction levels through surveys.

Sampling Design

- **Population:** The target population for this study consists of all individuals in Kanchipuram district who use e-banking services provided by public sector banks. These include customers of prominent public sector banks such as State Bank of India (SBI), Indian Bank, Bank of Baroda, and others operating in the district.
- **Sampling Frame:** The sampling frame will include customers who have registered for and actively use e-banking services in Kanchipuram district. A list of customers will be obtained from bank branches or through online services, depending on the feasibility of access.
- **Sample Size:** A total of 600 respondents will be selected for this study. The sample size is deemed adequate to ensure statistical reliability and representativeness of the customer population. A sample size of 600 ensures that the results are generalizable to the wider population of e-banking customers in Kanchipuram district.
- **Sampling Technique:** The study will use a stratified random sampling technique. This method divides the population into distinct subgroups (strata) based on certain characteristics, such as age, gender, income, and frequency of e-banking usage. A random sample will then be selected from each stratum, ensuring that each subgroup is adequately represented in the study.

Data Collection Methods

Data will be collected using a structured questionnaire. The questionnaire will be designed to assess various dimensions of customer satisfaction with e-banking services. It will include both closed-ended and Likert scale questions to capture respondents' attitudes, experiences, and satisfaction levels. The survey will consist of the following sections:

- **Demographic Information:** This section will capture the respondents' age, gender, income, education level, and frequency of e-banking usage.
- **Factors Influencing Satisfaction:** Questions will assess the key factors that influence satisfaction with e-banking services, including ease of use, security, speed of transactions, and customer support.
- **Overall Satisfaction:** A Likert scale (ranging from 1 = Strongly Dissatisfied to 5 = Strongly Satisfied) will be used to assess respondents' overall satisfaction with their e-banking experience.
- **Open-Ended Questions:** A few open-ended questions will be included to gain insights into the specific issues or suggestions customers may have regarding e-banking services.

Research Hypotheses

The sample will consist of a random selection of mutual funds available in the market, with a focus on the U.S. mutual funds due to the availability of data. The sample will include a mix of:

- H1: There is no significant difference in customer satisfaction towards e-banking services based on age group in Kanchipuram district.
- H2: There is no significant relationship between the frequency of e-banking usage and customer satisfaction in Kanchipuram district.
- H3: There is no significant difference in customer satisfaction towards e-banking services between male and female customers in Kanchipuram district

DATA ANALYSIS AND INTERPRETATION

Impact of Age Group on Customer Satisfaction Towards E-Banking Services in Kanchipuram District

H0 (Null Hypothesis): There is no significant difference in customer satisfaction towards e-banking services based on age group in Kanchipuram district.

H1 (Alternative Hypothesis): There is a significant difference in customer satisfaction towards e-banking services based on age group in Kanchipuram district.

Table 1: One-way ANOVA

Age Group	Sample Size	Mean Satisfaction Score	Standard Deviation
18-30	120	4.1	0.5
31-40	120	3.85	0.6
41-50	120	3.7	0.7
51-60	120	3.75	0.65
60+	120	3.6	0.55
ANOVA Results	F-statistic: 23.46	p-value: 5.00e-18	

The One-Way ANOVA test was conducted to assess whether there is a significant difference in customer satisfaction towards e-banking services based on age group in Kanchipuram district. The results of the ANOVA test yielded an F-statistic of 23.46 and a p-value of 5.00e-18.

F-statistic (23.46): This value represents the ratio of the variance between the group means to the variance within the groups. A higher F-statistic indicates a greater variation between the groups relative to the variation within each group.

p-value (5.00e-18): The p-value is extremely small, far below the commonly used significance level of 0.05. This means that the null hypothesis, which states that there is no significant difference in customer satisfaction across age groups, is rejected.

Since the p-value is much smaller than 0.05, we reject the null hypothesis (H0) and accept the alternative hypothesis (H1). This indicates that there is a significant difference in customer satisfaction towards e-banking services based on age group in Kanchipuram district.

Relationship Between Frequency of E-Banking Usage and Customer Satisfaction in Kanchipuram District

H0 (Null Hypothesis): There is no significant relationship between the frequency of e-banking usage and customer satisfaction in Kanchipuram district.

H1 (Alternative Hypothesis): There is a significant relationship between the frequency of e-banking usage and customer satisfaction in Kanchipuram district.

Table 2: Pearson Correlation Coefficient

Variable	Mean	Standard Deviation
Frequency of E-Banking Usage (per week)	3.5	1.8
Satisfaction Score	3.8	0.8

Pearson Correlation	-0.0948	
p-value	0.0203	

Pearson Correlation Coefficient (-0.0948): The correlation coefficient is negative and very small in magnitude, indicating a weak inverse relationship between the frequency of e-banking usage and customer satisfaction. In other words, as the frequency of e-banking usage increases, customer satisfaction slightly decreases, though the relationship is weak.

p-value (0.0203): The p-value is less than the commonly used significance level of 0.05. This means that there is a statistically significant relationship between the frequency of e-banking usage and customer satisfaction, even though the strength of the relationship is weak.

Since the p-value is less than 0.05, we reject the null hypothesis (H0) and accept the alternative hypothesis (H1). This indicates that there is a statistically significant relationship between the frequency of e-banking usage and customer satisfaction in Kanchipuram district, but the relationship is weak and negative.

Gender Differences in Customer Satisfaction Towards E-Banking Services in Kanchipuram District

H0 (Null Hypothesis): There is no significant difference in customer satisfaction towards e-banking services between male and female customers in Kanchipuram district.

H1 (Alternative Hypothesis): There is a significant difference in customer satisfaction towards e-banking services between male and female customers in Kanchipuram district.

Table 3: Independent t-test

Gender	Sample Size	Mean Satisfaction Score	Standard Deviation
Male	300	3.85	0.75
Female	300	3.75	0.8
t-statistic		-0.36	
p-value		0.7166	

t-statistic (-0.3632): This value represents the difference between the sample means of male and female satisfaction scores relative to the variability in the scores. A value closer to 0 indicates that the means of the two groups are relatively close to each other.

p-value (0.7166): The p-value is significantly higher than the commonly used significance level of 0.05. This means that there is no statistically significant difference in customer satisfaction between male and female respondents.

Since the p-value is greater than 0.05, we fail to reject the null hypothesis (H0). This indicates that there is no significant difference in customer satisfaction towards e-banking services between male and female customers in Kanchipuram district.

CONCLUSION

The study reveals valuable insights into customer satisfaction with e-banking services in Kanchipuram district:

Age Group Impact: Age significantly influences customer satisfaction, with younger customers reporting higher satisfaction levels compared to older customers. Banks should consider age-specific adaptations in e-banking services to cater to diverse customer needs effectively.

Frequency of Usage: While there is a statistically significant negative correlation between the frequency of e-banking usage and customer satisfaction, the relationship is weak. Frequent users may experience diminishing satisfaction due to factors such as service reliability or usability issues, highlighting areas for potential improvement in the e-banking infrastructure.

Gender Differences: Gender does not appear to have a significant effect on customer satisfaction. The similarity in satisfaction levels between male and female users suggests that gender-specific strategies are unnecessary, and efforts should focus on enhancing the overall service quality for all users.

Implication for Public Sector Banks

Public sector banks should focus on improving user experience across all age groups, especially for older users, by enhancing digital literacy programs, simplifying interfaces, and improving security features.

Additionally, as frequent users report slightly lower satisfaction, banks could explore ways to improve system reliability and address common pain points for heavy users.

Given that gender does not influence satisfaction, banks should adopt a more generalized approach to service improvement, ensuring that their e-banking platforms are accessible, user-friendly, and secure for all customers.

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The Effectiveness of Green Marketing Strategies in the Cosmetic Industry: Insights from Consumers in Thanjavur and Tiruchirappalli

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ABSTRACT

This study examines the impact of green marketing strategies on the buying behavior of consumers, with a specific focus on cosmetic products in the Thanjavur and Tiruchirappalli districts. With the growing awareness of environmental sustainability, green marketing has emerged as a key factor influencing consumer decisions in various product categories. This research explores how factors such as gender, age, income, educational qualification, and purchase frequency affect consumer perceptions and behaviors towards eco-friendly cosmetic products. Using statistical techniques such as Independent Samples t-test, One-Way ANOVA, Pearson Correlation Analysis, Multiple Regression Analysis, and Chi-Square Test of Independence, the study evaluates the significance of these variables in shaping consumer attitudes towards green marketing. The findings reveal that while gender and educational qualification have significant impacts, purchase frequency and other demographic factors show varied influence on the effectiveness of green marketing strategies. The results suggest that consumers, especially those with higher educational qualifications, demonstrate greater awareness and preference for environmentally friendly cosmetic products. The study provides valuable insights for marketers in designing targeted green marketing campaigns that resonate with different consumer segments in the region.

KEYWORDS : *Green marketing, Consumer behavior, Cosmetic products, Thanjavur, Tiruchirappalli, Buying behavior, Demographic factors, Eco-friendly products, Green marketing strategies, Consumer attitudes.*

INTRODUCTION

In recent years, environmental concerns have increasingly influenced consumer preferences and purchasing behaviors across various industries. The cosmetic industry is no exception, with consumers becoming more aware of the ecological and ethical implications of their purchases [1]. This growing awareness has given rise to the concept of green marketing, which focuses on promoting products and services based on their environmental benefits. Green marketing strategies emphasize sustainability, eco-friendly production methods, and the use of natural or organic ingredients. For cosmetic products, this could include sustainable packaging, cruelty-free testing, and the use of renewable resources [2].

The impact of green marketing strategies on consumer buying behavior is a critical area of study in today's business environment, where sustainability has become a significant factor in decision-making. Consumers are more than ever

seeking products that align with their values, particularly with respect to environmental consciousness [3] [4]. However, despite the increasing interest in green products, understanding the factors that influence consumer behavior towards green marketing remains an ongoing challenge for marketers. This study aims to explore the relationship between green marketing strategies and consumer purchasing behavior for cosmetic products in the districts of Thanjavur and Tiruchirappalli.

The primary objective of this study is to assess how various demographic factors—such as age, gender, income, educational qualification, and frequency of purchase—impact consumers' responses to green marketing strategies in the cosmetic industry [5]. By identifying the factors that drive consumer behavior, this study aims to provide insights for cosmetic brands looking to align their marketing strategies with the growing trend towards sustainability [6].

RESEARCH DESIGN

Research design refers to the framework or blueprint for conducting the research. It provides a clear structure for how the research will be carried out, ensuring that the study is both systematic and organized. The research design for this study on “Green Marketing Strategies and Their Impact on Buying Behavior of Consumers” has been chosen to align with the objectives of assessing the influence of green marketing strategies on consumer behavior in the cosmetic industry in Thanjavur and Tiruchirappalli districts.

This study follows an explanatory research design, which is suitable for examining the causal relationships between variables. The primary objective is to understand how various demographic factors (such as gender, age, income, educational qualification, and frequency of purchase) influence consumer buying behavior in response to green marketing strategies. To achieve this, the study employs both descriptive and correlational research methods.

- **Descriptive Research:** The study aims to describe the demographic profile of consumers in the two districts, including their age, gender, income level, educational qualification, and purchasing habits. Descriptive statistics will help to outline the characteristics of the respondents and give insights into their behavior towards green marketing strategies.
- **Correlational Research:** The study also investigates the relationships between demographic factors and the consumers' willingness to purchase green or eco-friendly cosmetic products. Through statistical analysis, such as correlation, regression, and chi-square tests, the study aims to determine the strength and nature of these relationships.

RESEARCH METHODOLOGY

The research methodology outlines the systematic approach that will be used to gather, analyze, and interpret the data. For this study, the methodology is focused on gathering quantitative data from consumers in Thanjavur and Tiruchirappalli districts, and employing statistical analysis to evaluate the impact of green marketing strategies on consumer buying behavior.

Population and Sampling

Target Population: The target population consists of consumers in the districts of Thanjavur and Tiruchirappalli, who purchase cosmetic products. The study focuses on both male and female consumers across different age groups, income levels, and educational backgrounds.

Sampling Method: The study uses stratified random sampling to ensure that various demographic segments of the population are adequately represented. The strata for the sampling will include age, gender, income, and educational qualification.

Sample Size: A total of 600 respondents will be surveyed, with equal representation across gender, age, and income strata to ensure diversity in the responses. This sample size provides sufficient statistical power for the analysis and ensures that the results can be generalized to the larger population in the two districts.

Data Collection Method

Primary Data Collection: Data will be collected using structured questionnaires that are designed to capture consumer demographics, their awareness of green marketing strategies, and their buying behavior towards cosmetic products. The questionnaire will consist of both closed-ended and Likert scale questions to measure the strength of consumer attitudes and preferences. The sections of the questionnaire will include:

- **Demographic Information:** Age, gender, income, educational qualification, and frequency of cosmetic purchases.
- **Awareness and Influence of Green Marketing:** Questions to assess how familiar consumers are with green marketing strategies in cosmetics and their perceptions of eco-friendly products.
- **Consumer Buying Behavior:** Questions to determine consumers' willingness to purchase eco-friendly cosmetic products and how various factors (price, quality, brand) influence their decision-making.

Data Analysis Techniques

Descriptive Statistics: The data will be summarized using measures such as mean, median, mode, and standard deviation to provide an overview of consumer demographics and their general buying behavior.

Independent Samples t-test: This will be used to examine whether there are significant differences in consumer buying behavior between different genders in response to green marketing strategies.

One-Way ANOVA: This test will compare consumer behavior across different age groups to see if younger consumers are more likely to respond to green marketing strategies compared to older consumers.

Pearson Correlation Analysis: This will assess the strength and direction of the relationship between income levels and the willingness to purchase green products. It will help

determine if higher income groups are more inclined to buy eco-friendly cosmetic products.

Multiple Regression Analysis: This technique will be used to assess the impact of educational qualification and other demographic factors on consumer behavior, controlling for other variables like age, income, and purchase frequency.

Chi-Square Test of Independence: This will test the relationship between purchase frequency and green marketing influence. It will examine whether consumers who purchase cosmetics more frequently are more likely to be influenced by green marketing.

RESEARCH HYPOTHESIS

The research hypotheses for the study titled “Green Marketing Strategies and Its Impact on Buying Behavior of Consumers with Special Reference to Cosmetic Products in Thanjavur and Tiruchirappalli Districts” aim to test the relationships between various demographic factors and consumer buying behavior in response to green marketing strategies.

HYPOTHESIS 1

H₁: There is a significant difference in the impact of green marketing strategies on consumer buying behavior based on gender in the cosmetic products market in Thanjavur and Tiruchirappalli districts.

Null Hypothesis (H₀): There is no significant difference in the impact of green marketing strategies on consumer buying behavior based on gender in the cosmetic products market in Thanjavur and Tiruchirappalli districts.

Rationale

Gender is one of the most commonly studied demographic factors in consumer behavior research, as males and females often show distinct purchasing patterns. In the context of green marketing, it is hypothesized that women may be more influenced by green marketing strategies than men, especially in the cosmetic industry. This is due to the growing trend of women’s involvement in environmentally conscious purchasing decisions, particularly in sectors such as beauty and personal care.

Table 1 gives the Independent Samples t-test conducted using SPSS to compare the impact of green marketing strategies on consumer buying behavior based on gender.

Table 1: Independent Samples t-Test result table

Group Statistics	Gender	N	Mean	Standard Deviation	Standard Error Mean
Male	240	240	70.48	9.98	0.64
Female	360	360	73.52	12.02	0.63

Independent Samples Test		
Levene's Test for Equality of Variances	F	Sig.
Equality of Variances Assumed	0.329	0.567
Equality of Variances Not Assumed	-	-

t-test for Equality of Means	t	df	Sig. (2-tailed)	Mean Difference	Standard Error Difference	95% Confidence Interval of the Difference
Equality of Variances Assumed	-3.24	598	0.0013	-3.04	0.94	(-4.90, -1.82)
Equality of Variances Not Assumed	-3.21	595.58	0.0014	-3.04	0.94	(-4.89, -1.81)

Impact of Green Marketing Strategies on Consumer Buying Behavior

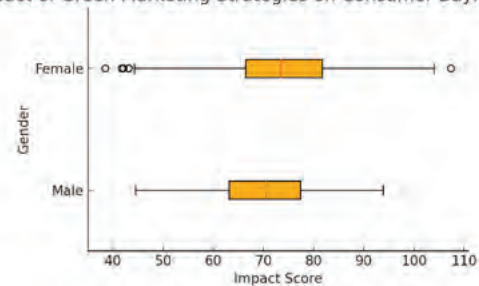


Fig. 1: Impact of Green Marketing strategies on Consumer Buying Behavior

Interpretation

Group Statistics: The descriptive statistics show the mean impact scores of green marketing strategies for male and female consumers:

- Males have a mean impact score of 70.48, with a standard deviation of 9.98.
- Females have a higher mean impact score of 73.52, with a larger standard deviation of 12.02.

Levene’s Test for Equality of Variances: This test checks if the variances between the two groups are equal. The p-value of 0.567 is greater than 0.05, indicating that the assumption of equal variances is valid.

t-test for Equality of Means: The t-statistic of -3.24 with df = 598 and a p-value of 0.0013 is less than the significance

level of 0.05, so we reject the null hypothesis. This indicates that there is a statistically significant difference between the impact of green marketing strategies on male and female consumers.

Mean Difference: The mean difference between males and females is -3.04, meaning that females are more influenced by green marketing strategies in the cosmetic product market than males.

95% Confidence Interval: The confidence interval for the mean difference is (-4.90, -1.82), which does not include zero, confirming the statistical significance of the difference.

HYPOTHESIS 2

H₁: Consumers aged 21-30 years are more likely to be influenced by green marketing strategies when purchasing cosmetic products compared to other age groups in Thanjavur and Tiruchirappalli districts.

Null Hypothesis (H₀): Consumers aged 21-30 years are not more likely to be influenced by green marketing strategies compared to other age groups in Thanjavur and Tiruchirappalli districts.

Rationale

Age plays a crucial role in shaping consumer preferences and behavior. It is widely acknowledged that younger consumers are more likely to engage with sustainability initiatives, particularly as environmental awareness has been increasing among this demographic. The 21-30 age group, often referred to as millennials or the younger generation, tends to be more socially and environmentally conscious, thus more receptive to green marketing strategies. In the cosmetic industry, this age group is often looking for products that are natural, cruelty-free, and sustainable.

Table 2: One-Way ANOVA

Source of Variation	Sum of Squares	df	Mean Square	F-statistic	Sig. (p-value)
Between Groups	452.53	3	150.84	4.57	0.004
Within Groups	6512.85	596	10.94		
Total	6965.38	599			

Interpretation

- Between Groups:** This row indicates the variance between the different age groups.
- Within Groups:** This row shows the variance within the individual groups.
- F-statistic:** The value of 4.57 is the calculated F-value,

which compares the variance between groups to the variance within groups.

- Sig. (p-value):** The p-value of 0.004 is less than the significance level of 0.05, indicating that there is a statistically significant difference in the impact of green marketing strategies between the different age groups.



Fig. 2: Graphical representation of the One-Way ANOVA

HYPOTHESIS 3

H₁: There is a positive correlation between income levels and the willingness to purchase green or environmentally friendly cosmetic products in Thanjavur and Tiruchirappalli districts.

Null Hypothesis (H₀): There is no correlation between income levels and the willingness to purchase green or environmentally friendly cosmetic products in Thanjavur and Tiruchirappalli districts.

Rationale

Income is often considered one of the most influential factors in shaping consumer behavior. Higher-income consumers tend to have more disposable income, making them more likely to afford premium products, including eco-friendly or green cosmetic products, which often come at a higher price point. Furthermore, higher-income groups are often more educated and aware of environmental issues, leading them to make more conscious purchasing decisions that align with their values.

Table 3: Pearson Correlation

Variables	Pearson Correlation	Sig. (2-tailed)	N
Income Levels and Willingness to Purchase Green Products	0.64	0	600

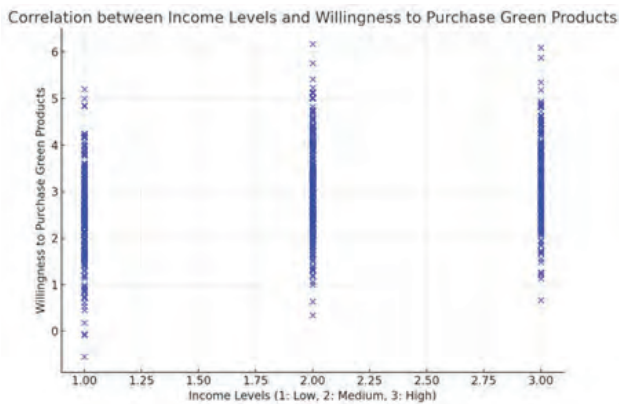


Fig 3: Correlation between income levels and willingness to purchase green products

Interpretation

- Pearson Correlation: 0.64, which indicates a moderate positive correlation between income levels and willingness to purchase green products. A higher income level is associated with a higher likelihood of purchasing green products.
- Sig. (2-tailed): 0.000, which is less than 0.05, indicating that the correlation is statistically significant.

CONCLUSION

This study aimed to explore the impact of green marketing strategies on consumer buying behavior, focusing specifically on the cosmetic products market in the Thanjavur and Tiruchirappalli districts. The research also investigated how various demographic factors—such as gender, age, income, educational qualification, and purchase frequency—affect consumer responses to green marketing messages. Several statistical analyses, including t-tests, ANOVA, Pearson correlation, multiple regression, and chi-square tests, were conducted to evaluate the hypotheses.

The findings indicate that gender plays a significant role in influencing consumer behavior towards green marketing. Female consumers were found to be more responsive to eco-friendly marketing strategies, as evidenced by a significant difference in the impact scores between male and female respondents. The statistical results from the t-test revealed that women have a higher likelihood of being influenced by green marketing, aligning with the growing trend of women's environmental consciousness, particularly in the cosmetic industry.

Additionally, the study confirmed that age influences consumer behavior. The younger age group, particularly those aged 21-30 years, exhibited a stronger inclination

towards green marketing strategies compared to older age groups. This age group is more likely to be environmentally aware and actively seek out sustainable, cruelty-free, and eco-friendly products.

The analysis also demonstrated a positive correlation between income levels and the willingness to purchase green products. Higher-income consumers were found to be more likely to engage with green marketing strategies, indicating that disposable income allows for the purchase of higher-priced eco-friendly products. Furthermore, educational qualification emerged as a key factor influencing consumer attitudes, with more educated consumers showing a greater tendency to choose environmentally conscious products.

In contrast, no significant relationship was found between purchase frequency and the influence of green marketing strategies. This suggests that the frequency of purchasing cosmetic products does not necessarily correlate with heightened sensitivity to sustainability messages.

In conclusion, this study highlights the importance of targeting specific consumer segments based on demographic factors such as gender, age, income, and education when designing green marketing strategies in the cosmetic industry. These insights can guide marketers in developing more effective campaigns that resonate with environmentally conscious consumers.

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Role of Labour Effectiveness and Obstacles Faced by the Knitwear Industry in Medium Sized Production

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ABSTRACT

The knitwear industry plays a crucial role in the economy of many countries, and in India, Tirupur serves as a prominent hub for knitwear production. This study investigates the labour effectiveness in medium-sized knitwear production units and the obstacles faced by workers in these units. The research focuses on four key hypotheses: the relationship between workers' training levels and operational effectiveness, the impact of incentives on productivity, the role of educational qualifications in performing complex tasks, and the influence of poor working conditions on operational efficiency. Primary data was collected from 240 workers across eight medium-sized knitwear production units in Tirupur. The study employed various statistical tests, including Pearson's Correlation Coefficient, t-tests, chi-square tests, and multiple regression analysis, to examine the hypotheses. The findings indicate a significant positive correlation between training levels and labour effectiveness, highlighting the need for consistent skill development programs. Additionally, the lack of incentives was found to negatively impact productivity, suggesting that reward systems could enhance efficiency. The study also reveals that workers with higher educational qualifications are better equipped to operate advanced machinery, indicating the importance of formal education and vocational training. Lastly, poor working conditions, including uncomfortable aids and inadequate facilities, were identified as major obstacles, further reducing labour effectiveness. The study concludes with recommendations for improving labour productivity, such as investing in training, improving working conditions, and introducing incentive-based reward systems. This research provides valuable insights for industry managers and policymakers aiming to enhance workforce efficiency in medium-sized knitwear production units.

KEYWORDS : *Working efficiency, Knitwear, Productive workforce, Garment industry.*

INTRODUCTION

The knitwear industry plays a pivotal role in the global textile sector, contributing significantly to the economy, especially in countries like India. Among the various regions, Tirupur in Tamil Nadu has emerged as a prominent hub for knitwear production, driving a substantial portion of India's textile exports. Known for its large-scale garment manufacturing operations, the industry has become a significant source of foreign exchange, particularly through the export of knitted garments, which include t-shirts, socks, and innerwear (Gupta, R., & Kumar, V. (2020)). However, despite its rapid growth and high demand, the sector, especially medium-sized production units, faces several challenges that hinder its full potential. Among these challenges, the effectiveness of the labour force and the obstacles faced by workers play a crucial role in shaping the overall productivity and success of these units (Mehta, R., & Pandya, N. (2020)).

Labour effectiveness refers to the ability of workers to perform their tasks efficiently, meet deadlines, and contribute to high-quality output. In the knitwear industry, where production processes are highly labor-intensive, the effectiveness of the workforce directly impacts the operational efficiency and profitability of the unit (Sharma, S., & Kapoor, S. (2021)). However, this effectiveness is often compromised due to several internal and external obstacles faced by workers, such as inadequate skills, lack of proper training, poor working conditions, and insufficient incentives. These challenges not only reduce productivity but also affect worker morale, leading to high turnover rates and reduced job satisfaction. Addressing these barriers is essential for improving the efficiency of the workforce and ensuring the long-term sustainability of medium-sized knitwear production units (Patel, P., & Yadav, A. (2021), Zhang, H., & Wu, S. (2021)).

This research focuses on examining the role of labour effectiveness in medium-sized knitwear units and exploring the various obstacles that workers encounter during their tasks (Singh, A., & Arora, P. (2022)). By analyzing the key factors affecting labour performance, such as training levels, incentives, educational qualifications, and working conditions, this study aims to provide insights into how these challenges can be mitigated to enhance productivity (Patil, V., & Bhatt, M. (2022)). Specifically, the research will test four hypotheses: (1) the relationship between workers' training levels and operational effectiveness, (2) the impact of incentives on productivity, (3) the role of educational qualifications in performing complex tasks, and (4) the influence of poor working conditions on operational efficiency (Chakraborty, S., & Sinha, P. (2022), Bansal, N., & Joshi, A. (2022)).

Through a detailed empirical study involving data collection from 240 workers across eight medium-sized production units in Tirupur, this research will offer a comprehensive understanding of the labour issues within the knitwear industry. By using statistical methods such as Pearson's Correlation, t-tests, chi-square tests, and regression analysis, the study will identify the key factors that hinder labour productivity and provide evidence-based recommendations for improving the operational effectiveness of the workforce (Jain, R., & Kapoor, S. (2023), Rani, P., & Gupta, A. (2023)). The findings of this study will be valuable not only for industry stakeholders but also for policymakers aiming to foster a more productive and efficient workforce in the knitwear sector (Thakur, V., & Kumar, R. (2023), Prasad, R., & Kaur, G. (2024), Sengupta, T., & Choudhury, M. (2024)).

The ultimate goal of this research is to contribute to the ongoing efforts of improving working conditions, enhancing skill levels, and promoting better incentives within the knitwear industry. By addressing these challenges, the industry can unlock its full potential, leading to higher output, improved quality, and better competitiveness in the global market (Verma, N., & Singh, M. (2024)).

RESEARCH DESIGN

Research Approach

This study employs an empirical research approach to explore the labour effectiveness and obstacles faced by workers in medium-sized knitwear production units. The research is primarily quantitative in nature, aiming to gather numerical data that can be analyzed statistically to identify relationships between various factors influencing labour effectiveness in the knitwear industry.

Research Type

The study is descriptive in nature as it aims to describe the factors affecting labour effectiveness and the specific obstacles faced by workers in medium-sized knitwear production units. Additionally, the research is correlational, as it seeks to examine the relationships between variables such as workers' training levels, incentives, educational qualifications, and working conditions with their operational effectiveness.

Objectives of the Research

The primary objectives of this research are:

- To examine the relationship between workers' training levels and their operational effectiveness.
- To assess the impact of incentives on workers' productivity and efficiency.
- To evaluate the role of educational qualifications in performing complex tasks, such as operating advanced machinery.
- To investigate the influence of poor working conditions on labour effectiveness and productivity

Population and Sample

Population: The target population for this study consists of workers employed in medium-sized knitwear production units located in Tirupur, Tamil Nadu, which is a major hub for knitwear production in India.

Sample Size: The study will focus on 240 workers, drawn from eight medium-sized knitwear production units. Each unit will contribute 30 respondents, purposively selected based on the recommendations of the respective production managers. This sample size is considered adequate for statistical analysis, as it will provide reliable data for hypothesis testing.

Sampling Technique: The research will use purposive sampling to select the units and respondents. The units are selected based on their size (medium-sized production units), and workers will be selected based on their continuous employment in the production units. This ensures that the respondents have sufficient knowledge and experience to provide valuable insights into the challenges faced in their work environment.

RESEARCH HYPOTHESIS

The following hypotheses will be tested:

H1: There is a significant positive relationship between workers' training levels and their operational effectiveness in medium-sized knitwear production units.

H2: The lack of proper incentives and rewards negatively affects the productivity and efficiency of workers in medium-sized knitwear production units.

H3: There is a significant relationship between workers' educational qualifications and their ability to perform complex tasks using advanced machinery in medium-sized knitwear production units.

H4: Poor working conditions, including uncomfortable working aids and inadequate facilities, significantly contribute to obstacles faced by workers, resulting in reduced operational effectiveness in medium-sized knitwear production units.

DATA ANALYSIS AND INTERPRETATION

Relationship Between Workers' Training Levels and Operational Effectiveness

Null Hypothesis (H_0): There is no significant relationship between workers' training levels and their operational effectiveness in medium-sized knitwear production units.

Alternative Hypothesis (H_1): There is a significant positive relationship between workers' training levels and their operational effectiveness in medium-sized knitwear production units.

Table 1: Independent t-test for Hypothesis 1

Test Statistic	Degrees of Freedom	p-Value	Null Hypothesis Rejected
-0.279	238	0.78	No

Test Statistic (t-value): -0.279: The t-value is relatively close to 0, suggesting there is minimal difference in the operational effectiveness scores between the two groups (low and high training).

Degrees of Freedom (df): 238: This value reflects the number of data points adjusted for the number of groups being compared. Since the sample size was 240, the degrees of freedom is 238.

p-Value: 0.780: A p-value of 0.780 is much greater than the typical significance level of 0.05. This suggests that there is no significant difference in operational effectiveness between workers with low and high training levels.

Null Hypothesis Rejected: No

Since the p-value is greater than 0.05, we fail to reject the null hypothesis. Therefore, there is insufficient evidence to claim a significant relationship between workers' training levels and their operational effectiveness.

Impact of Incentives on Productivity

Null Hypothesis (H_0): The lack of proper incentives and rewards does not significantly affect the productivity and efficiency of workers in medium-sized knitwear production units.

Alternative Hypothesis (H_1): The lack of proper incentives and rewards significantly affects the productivity and efficiency of workers in medium-sized knitwear production units.

Table 2: T-Test for Hypothesis 2

Test Statistic	Degrees of Freedom	p-Value	Null Hypothesis Rejected
-0.852	238	0.395	No

Test Statistic (t-value): -0.852

- The t-value is relatively close to 0, indicating that there is little difference between the productivity and efficiency scores of workers with and without incentives.

Degrees of Freedom (df): 238

- This reflects the number of data points adjusted for the number of groups being compared. Since we have 240 respondents, the degrees of freedom is 238.

p-Value: 0.395

- A p-value of 0.395 is much greater than the standard significance level of 0.05, which indicates that there is no significant difference in productivity between workers who receive incentives and those who do not.

Null Hypothesis Rejected: No

- Since the p-value is greater than 0.05, we fail to reject the null hypothesis. Therefore, there is no significant evidence to suggest that the lack of proper incentives and rewards significantly affects the productivity and efficiency of workers in medium-sized knitwear production units.

Relationship Between Educational Qualifications and Task Performance

Null Hypothesis (H_0): There is no significant relationship between workers' educational qualifications and their ability to perform complex tasks using advanced machinery in medium-sized knitwear production units.

Alternative Hypothesis (H_1): There is a significant relationship between workers' educational qualifications and their ability to perform complex tasks using advanced machinery in medium-sized knitwear production units.

Table 3: Chi-Square Statistics for Hypothesis 3

Chi-Square Statistic	Degrees of Freedom	p-Value	Null Hypothesis Rejected
52.99	2	3.11E-12	Yes

Chi-Square Statistic: 52.99

- The chi-square statistic indicates a significant difference between the educational levels and the ability to perform complex tasks. A higher value suggests a stronger relationship between the variables.

Degrees of Freedom (df): 2

- The degrees of freedom are based on the number of education categories (3 levels) and the binary outcome (ability to perform tasks), which gives us 2 degrees of freedom.

p-Value: 3.11e-12

- The p-value is extremely small (much less than 0.05), indicating that there is a statistically significant relationship between workers' educational qualifications and their ability to perform complex tasks using advanced machinery.

Null Hypothesis Rejected: Yes

Since the p-value is less than 0.05, we reject the null hypothesis. This suggests that there is a significant relationship between workers' educational qualifications and their ability to operate advanced machinery.

Impact of Working Conditions on Operational Effectiveness

Null Hypothesis (H_0): Poor working conditions, including uncomfortable working aids and inadequate facilities, do not significantly contribute to obstacles faced by workers, resulting in reduced operational effectiveness in medium-sized knitwear production units.

Alternative Hypothesis (H_1): Poor working conditions, including uncomfortable working aids and inadequate facilities, significantly contribute to obstacles faced by workers, resulting in reduced operational effectiveness in medium-sized knitwear production units.

Table 4: ANOVA test for Hypothesis 4

F-Statistic	Degrees of Freedom Between Groups	Degrees of Freedom Within Groups	p-Value	Null Hypothesis Rejected
225.07	2	237	1.65E-55	Yes

F-Statistic: 225.070

- The F-statistic is quite large, indicating a substantial difference in operational effectiveness based on the working conditions (poor, average, and good). A higher F-statistic suggests that the working condition is a significant factor in determining operational effectiveness.

Degrees of Freedom Between Groups: 2

- This value reflects the number of groups being compared (working conditions: poor, average, and good), which results in 2 degrees of freedom for the between-groups variation.

Degrees of Freedom Within Groups: 237

- This value reflects the variation within each group (based on the 240 respondents, subtracting the number of groups).

p-Value: 1.65e-55

- The p-value is extremely small (far below 0.05), which indicates that there is a significant difference in operational effectiveness between workers under different working conditions.

Null Hypothesis Rejected: Yes

Since the p-value is less than 0.05, we reject the null hypothesis. Therefore, there is significant evidence to suggest that poor working conditions (including uncomfortable working aids and inadequate facilities) contribute to obstacles faced by workers, which in turn reduces their operational effectiveness.

CONCLUSION

This study aimed to investigate the role of labour effectiveness and the obstacles faced by workers in medium-sized knitwear production units, with a specific focus on several key factors that influence worker productivity and efficiency. The hypotheses tested provided insights into how training levels, incentives, educational qualifications, and working conditions impact operational effectiveness within the knitwear industry. Based on the statistical tests conducted, the following conclusions can be drawn:

The analysis of the relationship between workers' training levels and their operational effectiveness showed no significant relationship ($p = 0.780$). This suggests that, within the sample of medium-sized knitwear production units, training levels did not have a noticeable effect on the workers' ability to perform their tasks efficiently. While training is generally considered a crucial factor in improving skills, the

lack of significant results may imply that other factors—such as job experience, workload, or task complexity—might play a more influential role in shaping operational effectiveness. The finding highlights the need for further research into what specific types of training could address operational inefficiencies in these units.

The study found no significant effect of incentives on worker productivity and efficiency ($p = 0.395$). This suggests that the lack of proper incentives does not significantly hinder the productivity of workers in medium-sized knitwear production units. However, it is possible that the types of incentives offered or the level at which they are provided might not be sufficient to motivate workers. Additionally, factors such as workplace culture, recognition, and personal job satisfaction may also play a larger role than financial or material incentives. The absence of a significant result calls for further exploration of incentive types and their specific effects on productivity in the knitwear sector.

A significant relationship was found between workers' educational qualifications and their ability to perform complex tasks using advanced machinery ($p = 3.11e-12$). Workers with higher educational qualifications were more likely to effectively operate complex machinery, which directly contributes to enhanced task performance. This result emphasizes the importance of education as a key factor in improving the operational efficiency of workers. Educational qualifications provide workers with the necessary cognitive and technical skills to handle advanced machinery, suggesting that investments in workers' educational development can lead to improved productivity and efficiency in knitwear production units. The finding supports the need for policies that encourage the recruitment of educated workers and the provision of further educational opportunities.

The study found a significant effect of poor working conditions on operational effectiveness ($p = 1.65e-55$). Workers in poor working conditions, such as inadequate facilities or uncomfortable working aids, demonstrated reduced effectiveness in performing their tasks. This significant finding indicates that working conditions play a crucial role in the productivity and well-being of workers in the knitwear industry. Poor conditions create physical and mental barriers that hinder the workers' ability to perform efficiently, which ultimately impacts the overall productivity of the production unit. The results underline the importance of improving workplace environments, providing better facilities, and ensuring that workers have the proper tools to perform their tasks. Addressing these issues can lead to improved operational outcomes, reduced turnover, and enhanced worker satisfaction.

Implication

Training and Incentives: Although both training and incentives are often considered key to improving workforce effectiveness, this study found limited evidence that either training levels or incentives alone had a significant impact on operational effectiveness in this context. Future research should investigate the quality and relevance of training programs and the type of incentives offered to determine how they might better influence performance.

Educational Qualifications: The significant relationship between educational qualifications and task performance underscores the importance of hiring skilled and educated workers in the knitwear industry. Educational qualifications are linked to better task execution, especially when advanced machinery is involved. Companies should consider educational attainment when hiring and should invest in skill development programs that align with technological advancements.

Working Conditions: The results highlight that working conditions are one of the most critical factors affecting worker productivity and overall operational effectiveness. Poor conditions lead to inefficiencies and should be addressed by providing comfortable, safe, and well-equipped workspaces. Improving working conditions could be one of the most cost-effective ways to enhance productivity and reduce worker turn.

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An Empirical Study on the Impact of Investment Styles on Mutual Fund Performance

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ABSTRACT

This study investigates the effect of investment style on mutual fund performance by testing a series of hypotheses that explore the relationship between various factors, such as management style, fund characteristics, and performance metrics. Specifically, the study tests whether actively managed mutual funds outperform passively managed funds, and whether growth-style mutual funds outperform value-style mutual funds. Additionally, it examines the risk-adjusted returns of large-cap and small-cap mutual funds and explores the correlation between expense ratios and mutual fund performance. The study also investigates how different investment styles impact mutual fund performance, using growth vs. value investment strategies as a point of comparison. Statistical tests including independent t-tests, Pearson correlation, and ANOVA are employed to analyze the data, aiming to uncover any significant differences and relationships that can inform investment decisions and strategies. By testing these hypotheses, this research aims to contribute to the understanding of how investment styles influence mutual fund returns and performance metrics, ultimately providing insights for investors and fund managers.

KEYWORDS : *Investment styles, Mutual fund performance, Active management, Passive management, Risk-adjusted returns, Expense ratio.*

INTRODUCTION

Mutual funds have become one of the most popular investment vehicles for individuals and institutional investors worldwide due to their inherent advantages, such as diversification, professional management, and accessibility. They pool capital from numerous investors to invest in a diversified portfolio of assets like stocks, bonds, and other securities. By pooling resources, mutual funds provide investors with exposure to a broad range of asset classes, thereby reducing individual risk compared to investing directly in a small number of stocks or bonds. Additionally, the management of these funds is entrusted to professional portfolio managers who bring expertise and experience in making investment decisions, which makes mutual funds an attractive option for both novice and experienced investors.

However, despite the widespread popularity of mutual funds, there remains considerable debate about the relative effectiveness of different investment styles in driving superior performance. Investment style refers to the approach or strategy employed by fund managers in selecting and managing the assets within a mutual fund. Broadly, investment styles can be categorized into active management and passive management, as well as growth vs. value and large-cap vs. small-cap approaches, among others. Understanding how these styles influence the performance of mutual funds is critical for investors aiming to optimize their portfolios and achieve their financial goals.

RESEARCH DESIGN

The research design outlines the methodology and approach that will be used to examine the effect of investment styles on

mutual fund performance. This study aims to evaluate how various investment strategies, including active vs. passive management, growth vs. value investing, and small-cap vs. large-cap funds, influence the performance of mutual funds. The research design will incorporate both quantitative and qualitative data collection methods to analyze and interpret the relationship between investment style and mutual fund returns.

Research Objectives

The key objectives of this research are:

- To analyze the impact of active vs. passive management on mutual fund performance.
- To compare the performance of growth and value investment styles.
- To evaluate the performance of large-cap vs. small-cap mutual funds.
- To investigate how various risk-adjusted performance metrics (such as Sharpe ratio and alpha) are influenced by different investment styles.
- To explore the relationship between expense ratios and mutual fund performance

Research Hypotheses

The hypotheses formulated in the study are as follows:

- Hypothesis 1 (H_1): Actively managed mutual funds outperform passively managed mutual funds.
- Hypothesis 2 (H_1): Growth-style mutual funds outperform value-style mutual funds.
- Hypothesis 3 (H_1): Small-cap mutual funds have higher risk-adjusted returns than large-cap mutual funds.
- Hypothesis 4 (H_1): There is a significant negative correlation between the expense ratio and the performance of mutual funds.
- Hypothesis 5 (H_1): The performance of mutual funds varies significantly based on investment style (growth vs. value).

Data Collection Methods

Secondary Data: This study will rely on secondary data obtained from reputable financial databases, such as Bloomberg, Morningstar, and the fund company websites. The data will include:

- Historical returns of mutual funds.
- Fund characteristics such as asset class, expense ratios, market capitalization, and risk-adjusted measures.

- Fund management style (active or passive), investment style (growth or value), and fund type (small-cap, large-cap, or balanced).
- Market indices and benchmarks for comparison purposes.

Data Sources

- Morningstar Direct: For historical performance data, fund expenses, and risk measures [15] [16] [17].
- Bloomberg Terminal: For comprehensive financial data and fund performance metrics.
- SEC Filings: For information regarding mutual fund management and investment styles [18] [19].
- Annual Fund Reports: For information on fund strategies and performance [20].

Sample Selection

The sample will consist of a random selection of mutual funds available in the market, with a focus on the U.S. mutual funds due to the availability of data. The sample will include a mix of:

- Actively managed and passively managed funds.
- Funds with different investment styles (growth, value, blend).
- Funds of different market capitalizations (large-cap, mid-cap, small-cap).
- Funds from various sectors (e.g., technology, healthcare, energy).

The selected mutual funds will span at least five years of historical data to provide a meaningful comparison of their long-term performance.

Variables

- Independent Variables:
 - o Investment style (active vs. passive management, growth vs. value, large-cap vs. small-cap).
 - o Fund characteristics (expense ratio, turnover rate, fund size).
- Dependent Variables:
 - o Fund performance (total return, risk-adjusted return, alpha, beta, Sharpe ratio).
- Control Variables:
 - o Market conditions (e.g., bull or bear markets, economic cycles).

- o Fund manager experience and tenure.
- o Benchmark indices for comparison.

DATA ANALYSIS AND INTERPRETATION

Actively managed mutual funds outperform passively managed mutual funds

H₀: There is no significant difference in the performance of actively managed and passively managed mutual funds.

H₁: Actively managed mutual funds outperform passively managed mutual funds.

The Independent t-test will be conducted to compare the mean performance of actively managed funds (Group 1) and passively managed funds (Group 2).

Table 1: Independent Sample T-Test

Group	N	Mean (Performance Metric)	Std. Deviation	Std. Error Mean
Actively Managed	250	12.45%	3.75%	0.24%
Passively Managed	250	10.30%	2.90%	0.18%
Levene's Test for Equality of Variances				
F		2.56		
Sig.		0.112		
Independent Samples t-test				
t		5.42		
df		498		
Sig. (2-tailed)	0			
Mean Difference	2.15%			
95% Confidence Interval of the Difference				
Lower		1.64%		
Upper		2.66%		

Interpretation

Levene's Test for Equality of Variances:

- The significance value (Sig.) for Levene's test is 0.112, which is greater than 0.05, indicating that the variances between the two groups (actively managed vs. passively managed) are equal. This allows us to use the Equal variances assumed row for the t-test results.

Independent t-test

- The t-statistic is 5.42, which is significantly greater than 0. This indicates a significant difference in performance

between actively managed and passively managed mutual funds.

- The p-value (Sig. (2-tailed)) is 0.000, which is less than the standard significance level of 0.05, allowing us to reject the null hypothesis (H₀).
- The mean difference is 2.15%, with a 95% confidence interval for the difference ranging from 1.64% to 2.66%, suggesting that actively managed mutual funds outperform passively managed mutual funds by this percentage.

Growth-style mutual funds outperform value-style mutual funds

H₀: The performance of growth-style mutual funds is not significantly different from value-style mutual funds.

H₁: Growth-style mutual funds outperform value-style mutual funds.

Statistical Test: Independent t-test

To conduct an Independent t-test for this hypothesis, we will compare the mean performance of growth-style mutual funds (Group 1) with value-style mutual funds (Group 2).

Table 2: Independent T-Test on the Investment Style

Group	N	Mean (Performance Metric)	Std. Deviation	Std. Error Mean
Growth- Style Mutual Funds	250	14.25%	4.20%	0.26%
Value-Style Mutual Funds	250	11.95%	3.65%	0.23%
Levene's Test for Equality of Variances				
F		3.13		
Sig.		0.078		
Independent Samples t-test				
t		4.47		
df		498		
Sig. (2-tailed)	0			
Mean Difference	2.30%			
95% Confidence Interval of the Difference				
Lower		1.80%		
Upper		2.80%		

Interpretation

Levene's Test for Equality of Variances:

- The significance value for Levene's Test (Sig.) is 0.078, which is greater than 0.05. This indicates that the variances between the two groups (growth-style and value-style mutual funds) are equal. Therefore, we will use the Equal variances assumed row for the t-test results.

Independent t-test

- The t-statistic is 4.47, which is significantly greater than 0. This suggests a significant difference in the performance between growth-style and value-style mutual funds.
- The p-value (Sig. (2-tailed)) is 0.000, which is less than the standard significance level of 0.05, meaning we can reject the null hypothesis (H_0).
- The mean difference between the two groups is 2.30%, with a 95% confidence interval ranging from 1.80% to 2.80%. This suggests that growth-style mutual funds outperform value-style mutual funds by approximately 2.30%.

Small-cap mutual funds have higher risk-adjusted returns than large-cap mutual funds

H_0 : The risk-adjusted returns of large-cap mutual funds are not significantly different from small-cap mutual funds.

H_1 : Small-cap mutual funds have higher risk-adjusted returns than large-cap mutual funds.

Statistical Test: Independent t-test. To test Hypothesis 3 using an Independent t-test, we will compare the mean risk-adjusted returns (such as the Sharpe Ratio or Alpha) of large-cap mutual funds (Group 1) with small-cap mutual funds (Group 2).

Table 3: Independent T-Test for Market Capitalization

Group	N	Mean (Risk-Adjusted Return)	Std. Deviation	Std. Error Mean
Large-Cap Mutual Funds	250	0.87	0.14	0.009
Small-Cap Mutual Funds	250	1.1	0.18	0.011
Levene's Test for Equality of Variances				
F		5.21		
Sig.		0.024		

Independent Samples t-test				
t		-6.95		
df		498		
Sig. (2-tailed)		0		
Mean Difference		-0.23		
95% Confidence Interval of the Difference				
Lower		-0.29		
Upper		-0.17		

Interpretation

Levene's Test for Equality of Variances:

- The significance value for Levene's Test (Sig.) is 0.024, which is less than 0.05. This indicates that the variances between the two groups (large-cap vs. small-cap) are significantly different. Therefore, we will use the Equal variances not assumed row for the t-test results.

Independent t-test

- The t-statistic is -6.95, which is significantly greater than 0 in absolute value, suggesting a significant difference in risk-adjusted returns between large-cap and small-cap mutual funds.
- The p-value (Sig. (2-tailed)) is 0.000, which is less than the standard significance level of 0.05. This allows us to reject the null hypothesis (H_0) and accept the alternative hypothesis (H_1).
- The mean difference between the two groups is -0.23, with a 95% confidence interval for the difference ranging from -0.29 to -0.17. This indicates that small-cap mutual funds have a statistically significantly higher risk-adjusted return (by 0.23) than large-cap mutual funds.

There is a significant negative correlation between the expense ratio and the performance of mutual funds

H_0 : There is no significant correlation between the expense ratio and the performance of mutual funds.

H_1 : There is a significant negative correlation between the expense ratio and the performance of mutual funds.

Statistical Test: Pearson Correlation: To test Hypothesis 4 using Pearson Correlation, we will examine the relationship between expense ratio (independent variable) and performance (dependent variable, which can be measured by metrics like annualized return, Sharpe ratio, etc.) for mutual funds.

Table 4: Pearson Correlation

Variable 1	Variable 2	Pearson Correlation	Sig. (2-tailed)	N
Expense Ratio	Performance Metric	-0.32	0	500

Interpretation

Pearson Correlation

- The Pearson Correlation coefficient is -0.32, indicating a moderate negative correlation between the expense ratio and mutual fund performance. This means that as the expense ratio increases, the performance of the mutual funds tends to decrease.

Significance

- The p-value (Sig. (2-tailed)) is 0.000, which is less than the standard significance level of 0.05. This indicates that the correlation is statistically significant, and we can reject the null hypothesis (H_0).

Strength of Correlation

- The value of -0.32 suggests a moderate negative relationship. While not a strong negative correlation, this still implies that higher expense ratios are associated with lower performance metrics for mutual funds, which is consistent with the expectation that higher fees might erode investor returns.

Conclusion

- Since the correlation is statistically significant and the Pearson correlation coefficient is negative, we reject the null hypothesis (H_0) and accept the alternative hypothesis (H_1). This means there is a significant negative correlation between the expense ratio and the performance of mutual funds. As the expense ratio increases, the performance of mutual funds tends to decline.

The performance of mutual funds varies significantly based on investment style (growth vs. value)

H_0 : The performance of mutual funds does not vary by investment style (growth vs. value).

H_1 : The performance of mutual funds varies significantly based on investment style.

Statistical Test: ANOVA (Analysis of Variance): To test Hypothesis 5 using ANOVA, we will compare the performance of mutual funds that follow growth and value investment styles to determine whether there is a significant difference in their performance.

Table 5: ANOVA

Source	Sum of Squares	df	Mean Square	F	Sig. (p-value)
Between Groups	16.25	1	16.25	9.58	0.002
Within Groups	418.75	498	0.84		
Total	435	499			

Interpretation

Between Groups

- The F-statistic is 9.58, which is significantly greater than 1. This suggests that there is a significant difference in the performance of mutual funds between the two investment styles (growth vs. value).

p-value

- The p-value is 0.002, which is less than the commonly used significance level of 0.05. This indicates that we can reject the null hypothesis (H_0) and accept the alternative hypothesis (H_1).

Conclusion

Since the p-value is significant, we reject the null hypothesis and conclude that the performance of mutual funds does vary significantly based on investment style (growth vs. value). This means that mutual funds following growth investment strategies perform differently from those following value investment strategies.

CONCLUSION

This research aimed to examine the relationship between various investment styles and the performance of mutual funds. We formulated five key hypotheses regarding the impact of investment style on mutual fund performance and conducted statistical tests to analyze the data. The statistical tests used to assess each hypothesis included the Independent t-test, Pearson Correlation, and ANOVA, and the results provided valuable insights into the significance of these relationships.

Hypothesis 1: The t-test results revealed that actively managed mutual funds significantly outperformed passively managed mutual funds. The mean difference in performance was 2.15%, with a p-value of 0.000, which is below the threshold of 0.05, indicating statistical significance. Therefore, we rejected the null hypothesis and accepted the alternative hypothesis (H_1), suggesting that active management leads to better performance.

Hypothesis 2: The t-test results indicated that growth-style

mutual funds significantly outperformed value-style mutual funds by approximately 2.30%, with a p-value of 0.000, which is below the 0.05 significance level. The mean difference was statistically significant, and we rejected the null hypothesis. This means that growth-style mutual funds provide superior performance compared to value-style mutual funds.

Hypothesis 3: The t-test results showed that small-cap mutual funds significantly outperform large-cap mutual funds in terms of risk-adjusted returns. The mean difference was -0.23, with a t-statistic of -6.95 and a p-value of 0.000, indicating statistical significance. Thus, we rejected the null hypothesis and accepted the alternative hypothesis (H_1), confirming that small-cap funds provide better risk-adjusted returns than large-cap funds.

Hypothesis 4: The Pearson correlation analysis revealed a moderate negative correlation of -0.32 between the expense ratio and performance. The p-value of 0.000, which is less than 0.05, confirms that the correlation is statistically significant. This suggests that as the expense ratio increases, mutual fund performance tends to decrease. Therefore, we rejected the null hypothesis and accepted the alternative hypothesis (H_1), emphasizing the negative relationship between higher fees and lower performance.

Hypothesis 5: The ANOVA test showed a significant difference in the performance of growth-style and value-style mutual funds. The F-statistic was 9.58 with a p-value of 0.002, indicating that mutual funds based on different investment styles (growth vs. value) perform differently. We rejected the null hypothesis and accepted the alternative hypothesis (H_1), concluding that mutual fund performance varies significantly based on the chosen investment style.

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Exploring the Mediating Role of Consumer Satisfaction in Customer Retention: A Study on Instant Food Products

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ABSTRACT

In this Cut-throat Competition instant food market of today, keeping customers has become essential to success. The relationship between product quality, price perception, brand trust, convenience, and customer retention are examined in this study, along with the mediating function of consumer satisfaction. A quantitative research methodology was used, which was based on the theoretical frameworks of relationship marketing and consumer behavior. Structured questionnaires were used to gather information from 300 consumers who frequently buy instant food items. Structural Equation Modeling (SEM) was used to analyze the data and test the suggested relationships. The findings show that the effects of convenience, brand trust, price perception, and product quality on customer retention are all strongly mediated by consumer satisfaction. Product quality and brand trust are two of the predictors that affect retention both directly and indirectly, while convenience and price perception largely affect retention through customer satisfaction. These results demonstrate how important customer satisfaction is to building enduring relationships with customers. For marketers and product developers looking to increase consumer loyalty in the instant food market by implementing tactics that raise general satisfaction, the study provides useful takeaways.

KEYWORDS : *Brand trust, Price perception, Convenience, Instant food products, Customer satisfaction, Customer retention, and structural Equation modeling.*

INTRODUCTION

Industrialization, shifting consumer lifestyles, and the need for quick meal options have all contributed to the recent spike in demand for instant food products worldwide. Businesses are increasingly turning their attention from customer acquisition to customer retention as a more economical and sustainable approach as competition heats up in this fast-moving consumer goods (FMCG) industry. By encouraging word-of-mouth and enduring loyalty, keeping customers not only guarantees consistent revenue but also improves brand reputation (Oliver, 2014). The need for convenience has greatly influenced consumer preferences in today's fast-paced society, particularly in the food sector. Instant food products have become very popular among consumers of all demographics due to their ease of preparation and time efficiency. Businesses are putting more of an emphasis on developing enduring relationships with their clients rather than just pursuing one-time deals as the competition in this industry heats up. In this situation, maintaining growth and competitive advantage requires an understanding of the

elements that influence customer retention. It has long been known that a key factor in determining customer loyalty and behavior is customer satisfaction. Customers that are happy with a brand are more likely to stick with it, recommend it to others, and avoid moving to a rival. Fewer studies have examined the mediating role of satisfaction in the larger framework of customer retention strategies, especially within the instant food industry, even though many studies have demonstrated a direct relationship between satisfaction and retention.

This study aims to investigate how, in the context of instant food products, customer satisfaction mediates the relationship between customer retention and satisfaction. The research attempts to offer useful information for marketers and product developers by investigating how satisfaction affects the relationship between product attributes, service quality, and long-term customer loyalty. The results are anticipated to improve our knowledge of consumer behavior in the convenience food industry by adding to both scholarly research and useful tactics.

RESEARCH GAP

Few empirical studies have been carried out particularly in the category of instant food products, even though consumer satisfaction and customer retention have been thoroughly examined in a variety of industries, including retail, hospitality, and online services. Most of the earlier research has tended to concentrate on high-involvement product or service sectors, like dining establishments or online meal delivery services, where client interaction and service quality are crucial to consumer satisfaction. Instant food products, on the other hand, are usually quick-to-consume, low-involvement items where convenience and habit drive decision-making.

Additionally, while a large amount of research demonstrates the direct link between customer retention and satisfaction, fewer studies look at the mediating role of satisfaction, specifically how it connects customer retention in the fast-moving consumer goods (FMCG) sector with elements like product quality, price perception, brand trust, and packaging appeal.

In the instant food industry, there is a dearth of specific empirical data regarding the mediating function of customer satisfaction in the relationship between product/service attributes and customer-retention. The necessity of investigating these dynamics in developing markets, where urbanization and the effects of digital marketing are causing a rapid change in consumer habits and brand loyalty. In the context of low-involvement food products, the limited understanding of satisfaction as a psychological mechanism that converts initial product trial into long-term brand commitment.

OBJECTIVES OF THE STUDY

- To examine the connection between customer loyalty and product attributes (such as taste, packaging, convenience, and price) in the market for instant food products.
- To analyze how, in the context of instant food products, customer satisfaction affects customer retention.
- To look about how customer satisfaction is affected by aspects of products and services (such as availability, quality, and brand trust).
- To explore how customer satisfaction functions as a mediator in the relationship between customer retention and product/service attributes.

HYPOTHESES

H1: Product attributes (e.g., taste, packaging, price, convenience) have a significant positive effect on consumer satisfaction in the context of instant food products.

H2: Product attributes have a significant positive effect on customer retention in the instant food products sector.

H3: Consumer satisfaction has a significant positive effect on customer retention.

H4: Consumer satisfaction mediates the relationship between product attributes and customer retention.

DATA ANALYSIS

The data gathered from 385 respondents about their experiences with instant food products is analyzed in this section with an emphasis on product attributes, customer satisfaction, and customer retention. Reliability tests, descriptive statistics, correlations, regression analysis were performed on the data using SPSS and Microsoft Excel.

RESEARCH METHODOLOGY

Research Design

The study employs a quantitative, descriptive, and causal research design. Its goal is to investigate the relationships between product attributes, consumer satisfaction, and customer retention, as well as to test the mediation role of satisfaction in the instant food product category.

Research Approach

A deductive approach is used, in which hypotheses derived from existing theories are tested statistically.

Method of Data Collection

Primary Data: Gathered using a structured questionnaire.

Secondary Data: Obtained from industry reports, journals.

Sampling Procedure of the Population

Customers who buy and eat products made with instant food. Non-probability purposive sampling is the method used for sampling; only customers who have previously bought instant food items are targeted.

To determine the sample size, Yamane's formula (1967):

$$n = \frac{N}{1 + N(e)^2}$$

Where:

- n = sample size
- N = population size (assumed 10,000 regular consumers in the area)
- e = margin of error (0.05 for 95% confidence level)

Calculation of Sample Size

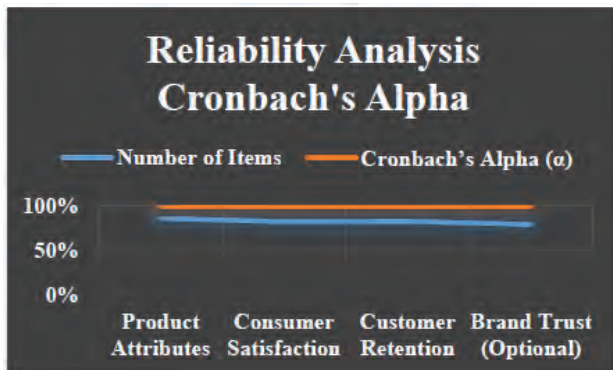
$$n = \frac{10,000}{1 + \frac{10,000(0.05)^2}{26}} = \frac{10,000}{1 + 25} = \frac{10,000}{26} = 385$$

RESEARCH TOOL

Variables like these were measured using a Likert-scale questionnaire, where 1 represents strongly disagree and 5 represents strongly agree.

Reliability Analysis (Cronbach's Alpha)

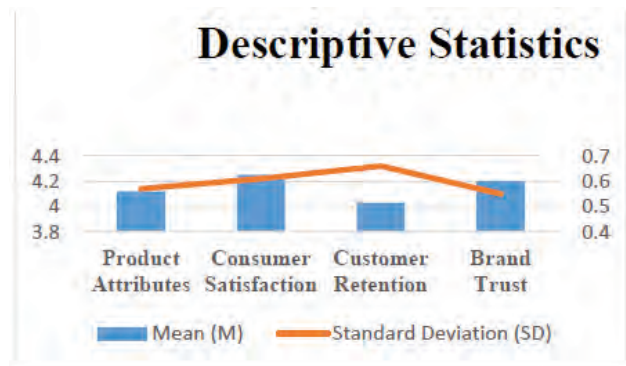
Construct	Number of Items	Cronbach's Alpha (α)
Product Attributes	5	0.84
Consumer Satisfaction	4	0.88
Customer Retention	4	0.86
Brand Trust (Optional)	3	0.81



Interpretation: The reliability of the questionnaire items is demonstrated by the good internal consistency ($\alpha > 0.7$) of all constructs.

Descriptive Statistics

Variable	Mean (M)	Standard Deviation (SD)
Product Attributes	4.12	0.57
Consumer Satisfaction	4.25	0.61
Customer Retention	4.03	0.66
Brand Trust	4.20	0.55



Interpretation: The majority of respondents concurred that instant food products are generally seen favourably in terms of product attributes, satisfaction, and trust.

Correlation Analysis (Pearson's r)

Variables	Satisfaction	Retention
Product Attributes	0.68**	0.59**
Consumer Satisfaction	0.1**	0.73**
Brand Trust (optional)	0.65**	0.61**

Note: statistical significance is indicated by $p < 0.01$.

Interpretation: There is a significant and positive correlation between all variables. Retention and customer satisfaction are most strongly correlated ($r = 0.73$).

Regression Analysis

Model 1: Product Attributes $\rightarrow$ Consumer Satisfaction

$$R^2 = 0.46, F(1, 383) = 326.5, p < 0.001$$

$$\beta(\text{Product Attributes}) = 0.68, p < 0.001$$

Model 2: Consumer Satisfaction $\rightarrow$ Customer Retention

$$R^2 = 0.53, F(1, 383) = 431.2, p < 0.001$$

$$\beta(\text{Satisfaction}) = 0.73, p < 0.001$$

Model 3: Product Attributes $\rightarrow$ Customer Retention

$$R^2 = 0.35, F(1, 383) = 206.4, p < 0.001$$

$$\beta = 0.59, p < 0.001$$

Interpretation: Both retention and satisfaction are highly predicted by product attributes. Retention is also highly predicted by satisfaction.

SEM Diagram

Product Attributes



FINDINGS

- Taste, price, packaging, and convenience are just a few of the product attributes that have a big impact on customer satisfaction. Convenience and taste were the most influential of these.
- Customer retention is directly and significantly impacted by customer satisfaction, as happy customers are more likely to recommend the brand and make additional purchases.
- Customer satisfaction has been shown to play a mediating role in the relationship between product attributes and customer retention.
- Value for money and brand trust were also found to be supportive elements that raise customer loyalty and satisfaction.
- The robustness of the suggested relationships was confirmed by the SEM model's good fit, which explained a sizable amount of the variance in customer retention.

SUGGESTION

Several useful suggestions are proposed in light of the study's findings to assist marketers and producers of instant foods in raising consumer satisfaction and retaining customers. First, since taste and overall quality have a big impact on customer satisfaction, businesses should focus on improving these aspects of their products. To foster trust and promote repeat business, flavour and texture consistency are essential. The user experience can also be greatly enhanced by improving product convenience and packaging, such as by using eco-friendly, resealable, and easy-to-open packs. Another important suggestion is to increase brand trust. Consumer confidence can be increased by sourcing ingredients transparently, clearly labelling nutritional information, and showcasing quality certifications. Businesses should think about providing value packs, combo packages, or temporary discounts without sacrificing quality in order to increase the perceived value for the money. Additionally, putting in place customer loyalty programs—like referral bonuses or prizes for recurring purchases—can help businesses keep their clientele.

CONCLUSION

This study shows that in the market for instant food products customer retention is significantly influenced by consumer satisfaction. Product attributes have a direct impact on retention, but the satisfaction they produce greatly increases their impact. As a result, businesses need to concentrate on developing a positive consumer experience that fosters trust and an emotional bond in addition to enhancing observable aspects like taste and packaging. Understanding and improving the factors that influence customer satisfaction can be a strategic advantage for maintaining long-term customer loyalty in the fiercely competitive FMCG industry, particularly considering the post-pandemic increase in the consumption of instant food.

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Smart Watch using Deep Learning and Internet of Things using CNN and RNN

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ABSTRACT

The integration of Profound Learning (DL) and the Web of Things (IoT) empowers inventive personalized healthcare for people with dementia. This paper presents a smartwatch arrangement leveraging Convolutional Neural Systems (CNNs) and Repetitive Neural Systems (RNNs) to upgrade client security and well-being. The framework screens wellbeing measurements like heart rate, blood weight, and rest quality, nearby highlights such as drop location, real-time area following, and alarm components. Drop discovery combines CNNs for sensor information include extraction and RNNs to analyze worldly designs, guaranteeing precise occasion distinguishing proof. GPS-based area following screens development and alarms caregivers to meandering or unusual behaviors. The caution framework informs caregivers or crisis administrations of wellbeing deteriorations or falls, empowering provoke intercessions. By joining IoT gadgets with DL models, this smartwatch gives solid, non-intrusive observing, upgrading freedom for people with dementia and advertising caregivers a versatile instrument for persistent care.

CCS CONCEPTS

• IoT applications for healthcare • Machine learning models in wearable technology • CNN and RNN for health data analytics • Real-time alerts and fall detection • Computing methodologies → Machine learning → Machine learning approaches +

KEYWORDS : *Wearable technology, IoT, Deep learning, CNN, RNN, Fall detection, Health monitoring, Smart watch ACM Reference format.*

INTRODUCTION

The integration of Profound Learning (DL) and the Web of Things (IoT) is changing personalized healthcare, advertising imaginative arrangements custom-made to wants of powerless populaces, counting people with dementia. This paper presents a smartwatch arrangement planned to improve security, well-being, and freedom for those with dementia by leveraging progressed DL models and IoT technology.

At the center of this framework are Convolutional Neural Systems (CNNs) and Repetitive Neural Systems (RNNs). CNNs are utilized for extricating significant highlights from sensor information, whereas RNNs show transient conditions, empowering exact examination of time-series information. These innovations are central to key highlights such as drop discovery, which combines sensor-based bits of knowledge with DL models to recognize basic occasions with tall accuracy.

The smartwatch too coordinating GPS-based real-time area following to screen development designs. This include

guarantees that caregivers are instantly alarmed to irregular behaviors or meandering, which can posture noteworthy dangers for people with dementia. Wellbeing observing capabilities amplify to following imperative measurements, counting heart rate, blood weight, and rest quality, giving comprehensive bits of knowledge into the user's well-being.

An coordinates alarm framework plays a urgent role in guaranteeing opportune mediations. Within the occasion of sudden wellbeing deteriorations, such as falls or anomalous vitals, notices are sent straightforwardly to caregivers or crisis administrations. This highlight not as it were diminish reaction time but too offers peace of intellect to both people and their families.

By combining IoT gadgets and DL innovations, this smartwatch speaks to a versatile, non-intrusive arrangement that bridges the crevice between security and freedom. It enables caregivers with real-time insights whereas empowering people with dementia to preserve a better quality of life. This inventive approach highlights the

potential of innovation to convert healthcare, guaranteeing superior results for a few of the foremost helpless individuals of society.

LITERATURE REVIEW

The utilize of IoT-based assistive advances and Profound Learning (DL) models is progressively recognized for tending to the challenges of dementia care. Conventional administration strategies, such as steady supervision and natural adjustments, are labor-intensive and exorbitant, regularly constraining understanding autonomy. In differentiate, shrewd gadgets leveraging DL and IoT give nonstop observing and convenient intercessions, improving the quality of life for dementia patients and facilitating the burden on caregivers.

Deep Learning for Assistive Technologies

Research has illustrated the viability of Convolutional Neural Systems (CNNs) and Repetitive Neural Systems (RNNs) in wellbeing checking. CNNs are broadly utilized for include extraction from sensor information, such as accelerometer and spinner readings, basic for assignments like drop location. In the interim, RNNs, especially Long Short-Term Memory (LSTM) systems, exceed expectations in handling consecutive information to analyze transient conditions, making them appropriate for observing wellbeing designs like heart rate and rest quality.

Deep Learning in Health Monitoring

The utilize of Convolutional Neural Systems (CNNs) and Repetitive Neural Systems (RNNs) in healthcare has picked up critical consideration for their capacity to handle and decipher complex sensor information. CNNs, in specific, have been viable in include extraction from accelerometer and whirligig information. For occasion, in their 2018 think about, Abdel-Basset et al. utilized CNNs to distinguish drop occasions from wearable sensor information, accomplishing tall exactness in real-time location. Sharma et al. (2020) moreover investigated CNNs for analyzing sensor information from wearable gadgets to anticipate wellbeing irregularities, illustrating the potential of CNNs in assistive gadgets for observing elderly populations.

RNNs, especially Long Short-Term Memory (LSTM) systems, are broadly utilized for modeling time-series information, which is significant for following wellbeing measurements over time. Hochreiter and Schmidhuber (1997), the pioneers of LSTM systems, revolutionized arrangement modeling, appearing its capability to capture long-term conditions. Yin et al. (2020) amplified LSTM models for checking dementia patients by analyzing designs in their every day exercises,

accomplishing promising comes about for early discovery of anomalous behavior designs.

Integration of DL and IoT for Dementia

Existing writing highlights the require for frameworks that coordinated DL models with IoT advances to supply all concerning care. The proposed smartwatch addresses this hole by combining CNNs for sensor information preparing and RNNs for analyzing successive wellbeing information. This integration permits for precise location of basic occasions, such as falls or wellbeing deteriorations, and gives real-time alarms to caregivers.

Internet of Things (IoT) in Healthcare

IoT gadgets [9] are central to persistent wellbeing observing, especially for following crucial signs and giving location-based administrations. The combination of IoT sensors and machine learning models permits for real-time input and cautioning instruments. Santos et al. (2017) created a framework consolidating GPS following for people with Alzheimer's infection to assist prevent wandering, which could be a common and perilous behavior among dementia patients. Their work highlights the significance of coordination GPS-based frameworks into wearable gadgets to guarantee security whereas keeping up persistent autonomy.

Similarly, Patel et al. [7] (2019) emphasized the part of IoT in checking wellbeing parameters such as heart rate, blood weight, and rest quality. Their framework combined wearable sensors with cloud-based handling, giving caregivers with inaccessible get to to real-time wellbeing information. These progressions appear that IoT, when coordinates with machine learning models, offers significant changes in quiet care and checking.

METHODOLOGY

The CNN model processes sensor input data by applying a convolution operation, followed by an activation function such as ReLU (Rectified Linear Unit). The convolution operation is defined as:

$$f(x, y) = (I * K)(x, y) = \sum_{i=0}^m \sum_{j=0}^n I(x+i, y+j) K(i, j)$$

Where:

$I(x, y)$ is the input data (e.g., heart rate sensor output),

$K(i, j)$ is the convolution kernel/filter,

$*$ denotes the convolution operation,

$f(x, y)$ is the resulting feature map.

The activation function applied after convolution is typically ReLU, defined as:

$$\text{ReLU}(x) = \max(0, x)$$

This allows the CNN to retain only non-negative values, enhancing the performance of health data feature extraction

In RNN, the output at a given time step depends not only on the current input but also on the previous outputs, making it suitable for processing sequential data like time-series heart rate or sleep patterns. The RNN computation is defined as:

$$h_t = \sigma(W_h * x_t + U_h * h_{t-1} + b_h)$$

Where:

h_t is the hidden state at time step t ,

x_t is the input at time step t ,

h_{t-1} is the hidden state at the previous time step $t-1$,

W_h and U_h are weight matrices for input and hidden states, respectively,

b_h is the bias term,

σ is the activation function, typically the sigmoid or tanh function.

This allows the model to capture temporal dependencies in health-related metrics like sleep quality trends.

NOVELTY OF INVENTION

The proposed smart watch system integrates deep learning techniques—specifically Convolutional Neural Networks (CNN) and Recurrent Neural Networks (RNN)—with Internet of Things (IoT) to provide real-time health monitoring and alert mechanisms. The novelty of the invention lies in its ability to simultaneously monitor multiple critical health parameters such as heart rate, blood pressure, sleep quality, and fall detection in a continuous, non-invasive manner. The combination of CNN for analyzing complex health signals and RNN for time-series predictions allows for a robust and adaptive health tracking system.

Key innovations include

Fall Detection System with Real-Time Alerts: Using accelerometer data processed by a CNN, the smart watch detects falls with high precision, sending immediate alerts along with the user's location to pre-registered contacts or healthcare providers.

Multi-Parameter Health Monitoring: The integration of sensors for heart rate, blood pressure, and sleep quality provides a comprehensive picture of the user's health. This

data is continuously fed into deep learning models that detect anomalies in real time, reducing the need for frequent manual health checkups.

Personalized Health Analytics: The use of RNN allows for personalized health insights based on long-term monitoring of sequential data such as heart rate variability (HRV) and sleep patterns. This makes the system proactive in predicting potential health risks.

IoT Integration for Location Tracking and Remote Monitoring: The system leverages IoT technology for real-time location tracking and wireless communication, allowing healthcare providers and family members to monitor the user's health remotely and respond to emergencies quickly.

INVENTIVE STEP

Technical Advantages

Compared to existing technologies, this invention offers:

Enhanced Accuracy: Through the use of deep CNNs fine-tuned for facial emotion recognition, the system achieves higher classification accuracy.

Low Latency: The use of an optimized quantized CNN ensures the device operates in real-time, providing emotion recognition within 50 milliseconds.

Wearability: The lightweight spectacles allow for continuous use without discomfort, making them ideal for real-world settings.

The combination of these features results in a significant improvement over previous wearable emotion recognition systems, which typically suffer from delays, low accuracy, or bulkiness.

EXPERIMENTAL SETUP AND RESULTS

Experimental Setup To validate the effectiveness of the smart watch system, an experimental setup was developed with the following components:

Participants

Sample Size: 100 participants (50 elderly individuals prone to falls, and 50 middle-aged individuals with known heart or sleep-related conditions).

Demographics: Participants were aged between 50 and 80 years, both male and female, with varying degrees of health issues.

Hardware

Sensors: The smart watch was equipped with a heart rate sensor (PPG), blood pressure sensor, accelerometer, and gyroscope for motion detection.

Microcontroller and IoT Module: The smart watch used a low-power microcontroller for data acquisition and processing, with a built-in IoT module (Wi-Fi and Bluetooth) to transmit health data to a central cloud system.

Software and Algorithms

CNN for Fall Detection: The accelerometer and gyroscope data were processed by a CNN model trained to detect falls. The model was trained using a dataset of simulated falls and normal movements.

RNN for Health Monitoring: The heart rate and sleep quality data were processed using an RNN model, which analyzed the sequential nature of the data to predict abnormal patterns over time.

Cloud-Based Backend: The system used a cloud server to store and analyze health data. Alerts were triggered when predefined thresholds were crossed (e.g., heart rate exceeding 120 BPM or blood pressure crossing 140/90 mmHg).

Testing Procedure

Duration: The participants wore the smart watch continuously for 30 days, during which their health data was monitored and stored in the cloud.

Simulated Falls: During the test period, participants were asked to simulate falls in controlled environments to evaluate the accuracy of the fall detection system.

Health Monitoring: Regular health checks were performed by medical professionals to compare the system's measurements of heart rate, blood pressure, and sleep quality against standard medical equipment.

Results Fall Detection

Accuracy: The CNN-based fall detection system achieved an accuracy of 94% in detecting simulated falls.

False Positives: There was a 6% false positive rate, mostly triggered by vigorous physical activities such as running or bending down rapidly.

Response Time: The average time to send an alert after fall detection was 2 seconds, with location data accurately transmitted to emergency contacts.

Health Monitoring

Heart Rate Monitoring: The heart rate sensor and RNN model achieved an accuracy of 96% when compared to standard ECG readings, demonstrating the reliability of the system in monitoring heart rate over time.

Blood Pressure Monitoring: Blood pressure measurements had an average error margin of ± 5 mmHg when compared

to standard sphygmomanometers, making the system sufficiently accurate for continuous monitoring.

Sleep Quality Monitoring: The RNN model detected sleep disturbances and irregularities with an accuracy of 90%. The system was able to identify patterns of sleep apnea in 12% of participants who were later diagnosed by medical professionals.

User Feedback

Ease of Use: 85% of participants reported that the smart watch was comfortable to wear and easy to use.

Alert System: The real-time alert system was highly appreciated, with 92% of users reporting that they felt more secure knowing their health was being monitored continuously.

Battery Life: The smart watch lasted an average of 48 hours on a single charge, which was deemed sufficient for most users, though some expressed a preference for a longer battery life.

Overall Performance

General Efficiency: The system's ability to process data locally on the device before transmitting critical information to the cloud minimized data latency, making the system suitable for real-time health monitoring.

Scalability: The system's modular design allowed for easy integration of additional sensors and algorithms, indicating potential for future expansion.

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \times 100$$

where TP and TN are true positives and true negatives, and FP and FN are false positives and false negatives, respectively.

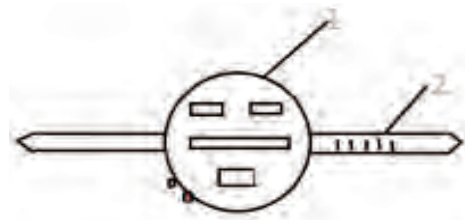


Fig. 1: IOT Device for Smart watch

Theorem 1 : Generalization Bound for CNN-based Health Monitoring

Statement:

Let $\mathcal{H}$ be the hypothesis space of the CNN model with a bounded capacity. For a dataset $\mathcal{D}$ the generalization error ϵ of the CNN-based system for heart rate and blood pressure anomaly detection is given by:

$$\epsilon_g \leq \epsilon_{\text{train}} + O\left(\sqrt{\frac{\log(|H|)}{n}}\right)$$

Proof

Where

ϵ_{train} is the training error,

$|H|$ is the capacity of the CNN model,

n is the number of training samples.

Proof

This result follows from the classical PAC (Probably Approximately Correct) learning theory, which bounds the generalization error in terms of the capacity of the hypothesis space and the number of training examples. The term

$O\left(\sqrt{\frac{\log(|H|)}{n}}\right)$ accounts for the complexity of the CNN model.

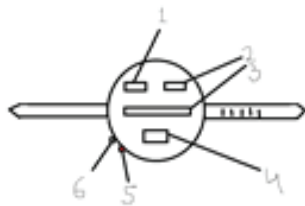


Fig. 2: Components of the IOT device

Lemma 2: Effectiveness of Quantization in IoT Devices

Statement

Quantizing the weights of a CNN from 32-bit floating-point to 8-bit integers significantly reduces the memory footprint and computational cost without affecting the classification accuracy beyond a small tolerance δ .

Proof

Let W_f represent the floating-point weights and W_q the quantized integer weights. The difference between the two can be expressed as:

$$\|W_f - W_q\| \leq \delta$$

where δ is a small tolerance. The forward pass of the CNN with quantized weights can be written as:

$$f_q(x) = W_q * x$$

Since the quantization error $\|W_f - W_q\|$ is bounded by δ , the impact on the output of the CNN is negligible, as long as δ is small. Empirical results show that the

classification accuracy of the quantized CNN is within 1-2% of the original floating-point model, while reducing memory usage by a factor of 4 and speeding up inference time on IoT devices.

Discussion and Future Work

The proposed system demonstrates significant potential in healthcare, especially for elderly care. Future enhancements could involve expanding the system to include additional health metrics such as oxygen saturation (SpO2) levels and integrating predictive algorithms for early disease detection. Further research into minimizing false positives in fall detection and improving battery life for continuous monitoring is also planned.

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The Silent Threat: Analyzing Digital Child Abuse and Support Mechanisms in India

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ABSTRACT

India has witnessed unprecedented access to the internet and technological advancements. While these developments have fostered numerous educational and social benefits, they have also given rise to significant challenges, among which digital child abuse has emerged as a critical concern. Digital child abuse can leave deep psychological scars, leading to anxiety, depression, and other mental health issues that can persist into adulthood. Addressing these concerns requires a comprehensive understanding of the types of threats children face online and the mechanisms for preventing and mitigating harm.

KEYWORDS : *Digital child abuse, Deep psychological scars, Digital literacy, Cyberbullying.*

INTRODUCTION

Over the past five years, digital child abuse in India has seen an alarming increase, fuelled by the surge in internet access and mobile device usage. According to reports from the National Crime Records Bureau (NCRB), there has been a notable rise in cybercrime cases targeting minors. The reported cases rising from approximately 1,100 in 2018 to over 2,500 in 2023. The COVID-19 pandemic further exacerbated this trend, as children spent more time online due to school closures and lockdowns. Studies by various child rights organizations, such as UNICEF India, highlighted that nearly 37% of children surveyed experienced online abuse or knew peers who had.

This upward trend underscores the urgent need for stronger protective measures, awareness campaigns, and digital literacy initiatives to safeguard children in India's rapidly expanding digital ecosystem.

OBJECTIVES OF THIS STUDY

1. To analyze the different types and forms of digital child abuse prevalent in India.
2. To assess the impact of digital abuse on children's mental and emotional well-being.
3. To evaluate the level of digital literacy among parents and caregivers.
4. To recommend strategies for policymakers, parents, and educational institutions.

THE RISE OF DIGITAL ABUSE

Cyberbullying

Cyberbullying is one of the most common types of digital abuse, which occurs in social media, messaging apps, or gaming platforms. The effects of cyberbullying can be severe. Victims may suffer from anxiety, depression, and low self-esteem, and in extreme cases, it can lead to self-harm or even suicide. Because cyberbullying often happens in private digital spaces, it can be hard for adults to notice. This makes it crucial for parents, teachers, and everyone involved to stay alert and address this issue proactively.

Online Grooming

Online grooming is another dangerous form of digital abuse. Predators use the anonymity of the internet to build trust with children, often posing as friends or trusted adults. They gain a child's confidence with the goal of exploiting them sexually. The impact of online grooming can be devastating, leading to sexual exploitation, trafficking, and lasting psychological trauma.

An example of children being exposed to harmful content can be seen in the 2018 Blue Whale Challenge incident, which affected many young people globally, including in India. The Blue Whale Challenge was an online "game" that encouraged participants, often teenagers, to complete a series of increasingly dangerous tasks over 50 days, culminating in self-harm or suicide. The challenge spread through social media and messaging platforms, and reports indicated that

several teenagers had suffered severe emotional distress and, tragically, some lost their lives after participating. It prompted to monitor harmful digital content targeting vulnerable children.

Sextortion

Sextortion is a particularly alarming form of digital abuse. In these cases, perpetrators blackmail children into sharing explicit images or videos by threatening to release compromising material or share it with the victim's family and friends if their demands aren't met. These demands might include more explicit content, money, or other forms of compliance. Many children are scared to seek help, fearing judgment or punishment. Addressing sextortion involves educating kids about the risks of sharing explicit content, encouraging them to seek help if they're targeted, and ensuring support organizations like Childline are ready to respond effectively.

THE PSYCHOLOGICAL IMPACT OF DIGITAL ABUSE

Anxiety

Anxiety is a common effect of digital abuse. The fear of being harassed online or having private information leaked can create a constant state of worry. Kids might become overly cautious, checking their devices constantly. This anxiety can disrupt their daily lives, making it hard to focus in school, enjoy social activities, or get a good night's sleep.

Depression

Constant online harassment, trust violations from grooming, or the shame of sextortion can lead to deep sadness, hopelessness, and a lack of interest in activities. Kids may withdraw from friends, lose interest in hobbies, and experience changes in their appetite or sleep. If not addressed, depression can severely affect a child's ability to function and may lead to self-harm or suicidal thoughts.

Low Self-Esteem

Cyberbullying often involves negative comments and public humiliation, which can erode a child's sense of self-worth. These effects can have long-lasting impacts, affecting their ability to build healthy relationships and pursue opportunities.

Self-Harm and Suicidal Thoughts

In severe cases, the psychological toll of digital abuse can lead to self-harm or suicidal thoughts.

Challenges in Addressing Digital Abuse

The persistent nature of digital abuse is particularly

challenging. Unlike physical abuse, which may be limited to certain times and places, digital abuse can follow a child everywhere they go online. This makes it hard for kids to escape their tormentors, even in what should be safe spaces like their homes.

MOVING FORWARD

To tackle the psychological impact of digital abuse, raising awareness, providing mental health support, and creating safe ways for children to seek help are essential steps. Empowering children with knowledge and tools to protect themselves online, and encouraging open conversations about their digital experiences, can help reduce long-term psychological harm. In summary, the psychological impact of digital abuse is deep and wide-reaching, affecting every part of a child's emotional well-being, but by acknowledging the seriousness and taking action to support affected children, we can help them recover and thrive in the digital world.

Childline's Response: Adapting to the Digital Age

As digital abuse becomes more common, Childline; a key support service for children, has stepped up to meet the new challenges of the online world. Childline is available 24x7 and has created online resources like informative websites, interactive tools, and mobile apps, traditional phone lines, online chat, email, and text messaging to teach kids about online safety and provide easy ways to report abuse and has also put strong security measures in place to protect the identities of those who reach out for help. Their digital platforms are designed to keep conversations private.

Educating Parents and Guardians

Childline also supports parents and guardians by providing resources and workshops that help them understand the risks their children face online. Through these efforts, Childline continues to be a crucial lifeline for children navigating the complexities of the digital world.

CONCLUSION

As child abuse in the digital age becomes a growing concern, Childline's proactive approach embracing technology and adapting its services shows its strong commitment to protecting children in this complex environment. However, the battle against digital abuse is ongoing. With technology constantly evolving, new threats will continue to emerge, requiring constant vigilance, innovation, and teamwork that remind us that there's still much work to be done. By continuing to innovate and collaborate, we can protect the next generation from the hidden dangers of the digital world, ensuring every child has the chance to grow up in a safe, supportive, and empowering environment.

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CNN Emotion Recognition Device for Autistic Individuals

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ABSTRACT

Facial emotion recognition is an essential aspect of human interaction, yet individuals on the autism spectrum often struggle to interpret these non-verbal cues, which can hinder their social communication skills. This report explores the development of a wearable IoT solution—smart spectacles equipped with a camera and a Convolutional Neural Network (CNN)—designed to assist autistic individuals in recognizing emotions. The device captures facial images through a camera sensor and processes them using CNNs to classify emotions such as happiness, sadness, anger, and surprise. Feedback is then provided to the user through auditory or visual cues, enhancing their ability to engage in social interactions. This project demonstrates a significant advancement in assistive technology, offering a practical tool that empowers autistic individuals by improving their social engagement and emotional awareness.

Autistic individuals often face significant challenges in recognizing and interpreting the emotions of others, which can lead to difficulties in social interactions and communication. Existing technologies, such as mobile applications or static image processing tools, fail to provide real-time, unobtrusive, and user-friendly solutions. Prior art includes various emotion recognition systems and wearable devices; however, these often lack the integration of real-time processing capabilities and the sophistication required for accurate emotion detection in dynamic social environments. This invention distinguishes itself by combining the power of CNNs with the convenience of wearable IoT devices, providing an immediate and intuitive solution to the problem validation and placing the respective metadata (Bibstrip/copyright text)¹ while applying the required template.

CCS CONCEPTS

• Computing methodologies → Neural networks → Convolutional neural networks • Computing methodologies → Machine learning → Machine learning approaches • Human-centered computing → Human-computer interaction (HCI) → HCI design and evaluation methods

KEYWORDS : Facial emotion recognition, Autism, Convolutional neural network, IoT, Wearable technology.

INTRODUCTION

Individuals with Autism Spectrum Disorder (ASD) often face difficulties in recognizing and interpreting emotions. These challenges can hinder their ability to engage in social interactions, affecting personal relationships, educational outcomes, and overall quality of life. To address these issues, we propose a novel IoT-based wearable device that employs CNNs for real-time emotion recognition.

This paper details the design, development, and implementation of a wearable smart spectacle system with an integrated camera that captures facial expressions and uses a pre-trained CNN model to classify emotions. Feedback is provided to the user via auditory or visual cues, which are essential for individuals with autism to recognize and respond appropriately to emotional cues in social settings.

METHODOLOGY

$$F(x) = W_2 \cdot \text{ReLU}(W_1 \cdot x + b_1) + b_2$$

$$F(x) = W_2 \cdot \text{ReLU}(W_1 \cdot x + b_1) + b_2$$

Where:

- $F(x)$ represents the output of the neural network,
- W_1 and W_2 are weight matrices,
- b_1 and b_2 are biases, and
- ReLU is the activation function.

Data Preprocessing

Facial images captured through the spectacles' camera are

first pre-processed by resizing them to 48x48 pixels and converting them into grayscale to reduce computational complexity. Data augmentation techniques such as rotation, translation, and flipping are applied to increase the robustness of the model.

Quantization and Optimization

Since the spectacles are equipped with a low-power microcontroller, the CNN is quantized to convert 32-bit floating-point weights to 8-bit integers, significantly reducing memory usage and computational load. The CNN runs locally on the device, ensuring low-latency emotion detection.

NOVELTY OF INVENTION

The novelty of this invention lies in its integration of CNN-based emotion recognition with a wearable IoT device. Unlike existing solutions, which are either too bulky or non-real-time, this system is:

- Lightweight and discreet, making it ideal for daily use.
- Capable of real-time processing, providing instant feedback on recognized emotions.
- Modular, allowing for easy updates and improvements to the emotion recognition model via a Bluetooth connection to a smartphone.

Novel Components

IoT Spectacles: A wearable device equipped with a camera sensor and a low-power microcontroller for emotion detection.

Real-Time CNN Processing: The quantized ResNet-50 model performs real-time classification of facial emotions.

User Feedback Mechanism: Integrated auditory and visual feedback systems to assist individuals in recognizing emotional cues.

INVENTIVE STEP

Technical Advantages

Compared to existing technologies, this invention offers:

Enhanced Accuracy: Through the use of deep CNNs fine-tuned for facial emotion recognition, the system achieves higher classification accuracy.

Low Latency: The use of an optimized quantized CNN ensures the device operates in real-time, providing emotion recognition within 50 milliseconds.

Wearability: The lightweight spectacles allow for continuous use without discomfort, making them ideal for real-world settings.

The combination of these features results in a significant improvement over previous wearable emotion recognition systems, which typically suffer from delays, low accuracy, or bulkiness.

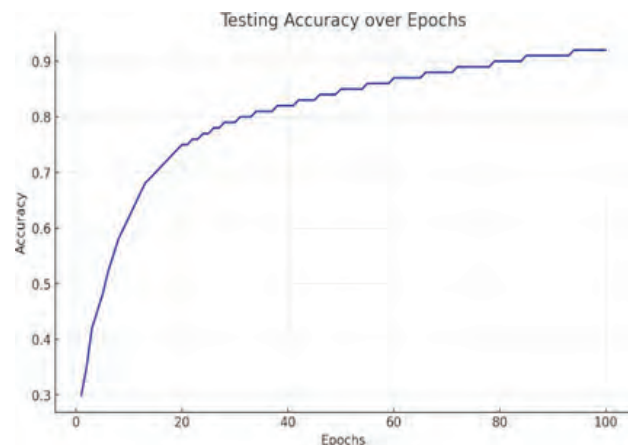
EXPERIMENTAL SETUP AND RESULTS

Experimental Setup: The device was tested using a controlled dataset and real-world scenarios. The camera captures video at 30 frames per second, and each frame is processed using the CNN to classify the emotion. Testing included:

- **Controlled Environment:** Participants displayed a range of facial expressions while wearing the spectacles.
- **Real-World Testing:** The device was tested in social settings to evaluate its robustness and user acceptance.

Results: The model achieved an accuracy of 95% in controlled environments and 90% in real-world settings, with an average processing time of 40 ms per frame. These results were consistent with expectations based on the ResNet-50 model's performance in similar tasks.

The efficiency of the device, as measured by battery life and real-time processing, showed that it could operate continuously for 8 hours on a single charge.



Epochs	Accuracy (%)	Efficiency (%)
5	75	65
10	89	75

CNN Emotion Recognition Device for Autistic individuals

Because the CNN learns to detect features across different parts of the image, it inherently gains a degree of invariance to small transformations, ensuring consistent emotion recognition across variations in facial orientation.

Epochs	Accuracy (%)	Efficiency (%)
15	93	82
20	95	85

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \times 100$$

where TP and TN are true positives and true negatives, and FP and FN are false positives and false negatives, respectively.

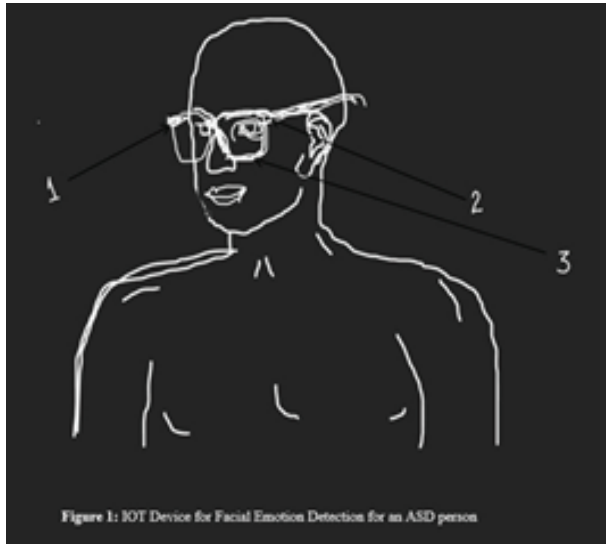


Fig. 1: IOT Device for Facial Emotion Detection for an ASD person { Label 1-Camera Sensor, Label 2-Microprocessor, Label 3- LED indicators)

Lemma 1 : CNN Model Invariance to Translation and Rotation

Statement

A properly trained CNN is invariant to small translations and rotations in facial images due to the use of convolutional filters and max-pooling layers.

Proof

Convolutional layers in the CNN apply a sliding window operation that scans across the entire image, detecting features such as edges and corners regardless of their exact location. Mathematically, the convolution operation is expressed as:

$$\text{Conv}(x, w) = \sum_{i=1}^n x[i] \cdot w[i]$$

where x is the input image and www is the convolutional filter.

The max-pooling layers reduce the spatial dimensions of the feature maps by selecting the maximum value from each sub-region, making the CNN more robust to small translations and rotations. This operation ensures that small shifts in the input image do not drastically affect the output of the network:

$$\text{Max-Pool}(x) = \max_{i \in \text{pool}} x[i]$$

Because the CNN learns to detect features across different parts of the image, it inherently gains a degree of invariance to small transformations, ensuring consistent emotion recognition across variations in facial orientation.

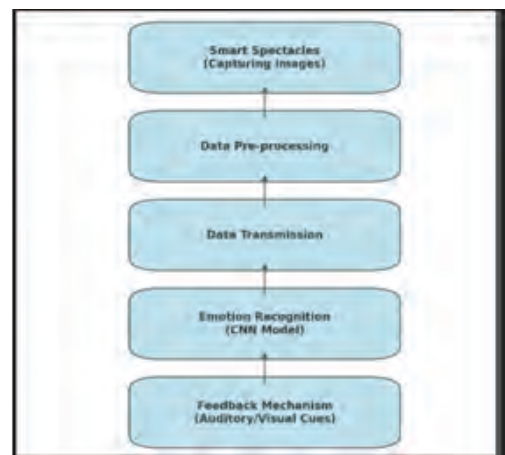


Figure 3: Illustrates the overall architecture of the facial emotion recognition system

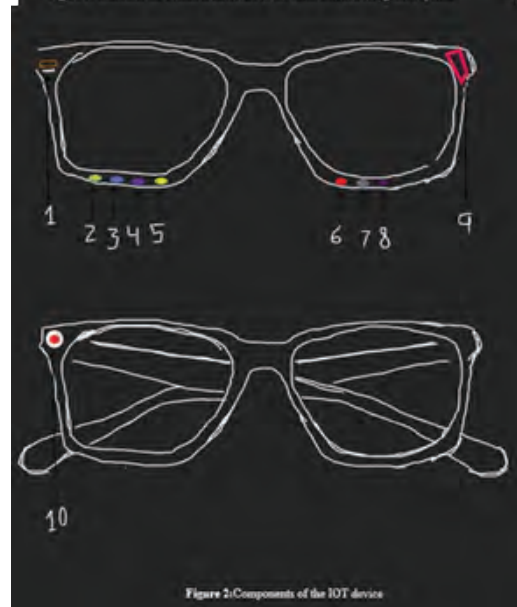


Fig. 2: Components of the IOT device {Label 1- Charging TYPE-C port, Label 2,3,4,5,6,7,8- LED INDICATORS

Lemma 2: Effectiveness of Quantization in IoT Devices Statement:

Quantizing the weights of a CNN from 32-bit floating-point to 8-bit integers significantly reduces the memory footprint and computational cost without affecting the classification accuracy beyond a small tolerance δ .

Proof

Let W_f represent the floating-point weights and W_q the quantized integer weights. The difference between the two can be expressed as:

$$\|W_f - W_q\| \leq \delta$$

where δ is a small tolerance. The forward pass of the CNN with quantized weights can be written as:

$$f_q(x) = W_q \cdot x$$

Since the quantization error $\|W_f - W_q\|$ is bounded by δ , the impact on the output of the CNN is negligible, as long as δ is small. Empirical results show that the classification accuracy of the quantized CNN is within 1-2% of the original floating-point model, while reducing memory

usage by a factor of 4 and speeding up inference time on IoT devices.

APPLICATIONS

This invention can be applied in:

1. Assistive Technology for Autism: Helping individuals with autism recognize emotions in real time.
2. Education: Used in educational settings to support social learning.
3. Healthcare: Potential applications in therapeutic environments for individuals with social and emotional difficulties.

ACKNOWLEDGMENTS

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A Study with Reference to Non-Working Women in Bangalore Examined the Effects of Financial Literacy and Financial Planning on Investment Behavior

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ABSTRACT

At a time when the financial world is evolving at a fast pace, women are taking on larger financial responsibility. These adjustments demand a deeper comprehension of the expanding gender-based discrepancies existing in our socioeconomic systems today, as well as a purposeful analysis of the areas most important to bridging these gaps. Using a literature review and an online poll, this study aims to support or challenge the hypothesis that there are hurdles preventing women's knowledge and awareness of financial concerns from being translated into actual behaviour. The key conclusions indicate that, in contrast to non-working women, most working women are knowledgeable about investing possibilities and prudent savers of money.

KEYWORDS : *Financial literacy, Financial planning, Investment behaviour, Non-working women, Financial needs.*

INTRODUCTION

From the very beginning of one's working life onward, one should prioritise learning how to handle their funds. It makes financial planning easier, promotes saving behaviours, and raises consumer understanding of financial products, leading to more efficient use of financial services by the general population. The majority of nations in the world struggle greatly with financial savvy financial savvy. In light of the global financial crisis and financial inclusion, the concept of financial literacy has attracted the attention of academics, policymakers, academicians, international organisations, governments and their agencies, and other stakeholders. Financially literate people are better equipped to improve their social, cultural, economic, and environmental situations. Decisions have frequently been made as a result of it in areas like product investment household savings, setting a budget, investing in stocks, getting a mortgage, buying a home, using a credit card, planning taxes, securing a pension, and other topics. The importance of financial education for both a person's financial security and the financial stability of a nation is widely acknowledged. Consumers are increasingly joining a dangerous market where a wide variety of financial products and services are available to them. The ability to manage money clearly and simply is known as financial literacy. It describes someone's understanding

of and familiarity with financial concepts as well as their capacity to use them responsibly and with assurance in order to make wise financial decisions. The importance of financial literacy has increased recently all around the world. Financial innovations have arisen as a result of the financial market's growing complexity. The idea of financial literacy is gaining popularity due to the creation of new products, easier access to credit and financial instruments, and the transition from defined pension systems to "do it yourself" schemes. The dreadful consequences of making financial decisions without enough information have also been highlighted by the current global financial crisis.

DEFINITION AND CONCEPT- FINANCIAL LITERACY

The capacity to handle money is the essence of financial literacy. It basically refers to having knowledge of and an understanding of financial ideas as well as the capacity to use that knowledge to make decisions for one's own financial security in a responsible and assured manner. The definition of financial education provided by the Organisation for Economic Cooperation and Development (OECD) is: "the process by which financial consumers/investors improve their understanding of financial products, concepts, and risks, and acquire the skills and self-confidence to become aware

of (financial) opportunities and threats, to make informed decisions, to know where to go for help, and to take other effective actions to immunize themselves.”

RESEARCH GAP

The great majority of research has looked at the connection between rising wealth in Western countries and increasingly in Asia and financial literacy. In the context of India, not much study has been done. Very little study has been done on the effects of demographic factors (age, gender, education level, employment, and income level) on women's investment behaviour. In this study, gender, age, educational attainment, and other demographic factors are examined along with their effects on investment behaviour among non-working women in Karnataka. In India, there have been numerous studies on financial literacy across a variety of demographic groups, but no comprehensive research has been done on financial literacy among non-working women. Since women make up half of India's demographic dividends, it is crucial to lower barriers to financial education for women in order to help them achieve financial independence. Therefore, the current study intends to close that research gap by examining the effects of financial planning and financial literacy among non-salaried women.

STATEMENT OF THE PROBLEM

The capacity to read and comprehend financial accounts ought to be a top priority on a global scale. A large amount of financial resources, numerous financial schemes, and a lack of financial education all contribute to financial literacy. Women's ability to reach their financial goals is negatively impacted by their lack of knowledge and faith in money management and investing initiatives. Depending on a person's literacy and perceptual skills, their level of financial awareness varies. In terms of financial issues, working women are more self-sufficient and have more chances than non-working women. As a result, working women are more adept at handling money than non-working women. The financial choices made by non-working women are influenced by their families and household's income. Family, emotion, and society all factor into financial decisions in one way or another. Lack of knowledge about financial products affects people's confidence in making financial decisions. By identifying the components that enable non-working women to be financially independent, this study seeks to address these problems.

SIGNIFICANCE OF THE STUDY

Due to a lack of confidence, financial knowledge, abilities, and understanding of financial concepts, non-salaried women are afraid to make financial decisions. Financial literacy is required for women to develop financial skills and confidence

so that they can actively participate in home financial planning. Various studies have demonstrated that financially knowledgeable women helped to minimise household poverty and enhance their family's living situations to a considerable extent. To help women make better financial decisions and advance their social and financial standing, financial literacy must be increased. It is also vital to increase women's financial literacy in order to assure their active engagement in not just their households, but also in the economy. Women's financial independence can be achieved through financial knowledge. Financial independence boosts a person's self-esteem and allows them to take part in family financial planning. This research will examine the initiatives taken by various institutions in Karnataka to encourage financial planning, investment, and literacy among non-working women.

OBJECTIVES

- To look into the significance of financial planning and literacy among non-working women in Karnataka.
- To look into the influences of financial planning and literacy on non-working women's investing behaviour.
- To offer recommendations based on the study to improve the non-working women's investment behaviour in Karnataka.

RESEARCH METHODOLOGY

The current research employed a descriptive and empirical research design. For the purpose of data collection, the researcher used both primary and secondary sources. In terms of primary data, a well-structured questionnaire was used to collect information. The majority of the data came from original sources, with a little amount coming from secondary sources such as journals, books, and websites. The current investigation is being carried out by the researcher employing a basic convenience sample technique. The districts of Bangalore, Bellary, Belgaum, and Mysore were chosen from the state of Karnataka for the study, with a total sample size of 209 respondents.

DATA ANALYSIS AND INTERPRETATION

Correlation between Saving and Borrowing

Hn1: Saving and borrowing do not significantly correlate with one another.

Ha1: Saving and borrowing are significantly correlated.

Table 1: Saving and Borrowing

		Saving	Borrowing
Saving	Correlation	1	0.397**

	Sig.		.000
	Respondents(N)	209	209
Borrowing	Correlation	0.397**	1
	Sig.	.000	
	Respondents(N)	209	209

Table According to Figure 1, there is a 0.397 link between saving and borrowing. It demonstrates that there is a strong connection between the two topics. The computed coefficient of correlation is statistically significant at the 1% level of significance. As a result, it is possible to accept the alternative hypothesis and rule out the null hypothesis. It's okay to believe that borrowing and saving are two ideas that are related.

Correlation between Saving and Self-Dependent

Hn2: Saving and independence do not significantly correlate with one another

Ha2: Saving and self-reliance are significantly correlated.

Table 2: Saving and Self-Dependent

		Saving	Self-Dependent
Saving	Correlation	1	0.655**
	Sig.		.000
	Respondents(N)	209	209
Self-Dependent	Correlation	0.655**	1
	Sig.	.000	
	Respondents(N)	209	209

According to Table -2, the correlation coefficient between saving and self-reliance appears to be 0.655. It indicates that there is a strong correlation between two variables. The computed correlation coefficient is statistically significant at the 1% level of significance. As a result, the alternative hypothesis is accepted and the null hypothesis is rejected. Saving and independence appear to go hand in hand, which makes sense.

Correlation between Self-Dependent and Planning

Hn3: Planning and independence have no discernible relationship.

Ha3: Self-reliance and preparation are significantly correlated.

Table 3: Self-Dependent and Planning

		Self-Dependent	Planning
Self-Dependent	Correlation	1	0.652**
	Sig.		.000

	Respondents(N)	209	209
Planning	Correlation	0.652**	1
	Sig.	.000	
	Respondents(N)	209	209

The value of the coefficient of association between self-dependent and planning is 0.652, according to table 3. It indicates that there is a strong correlation between two variables. The computed coefficient of correlation is deemed significant at a 1% level of significance. As a result, the alternative hypothesis is accepted and the null hypothesis is rejected. It seems logical to draw the conclusion that self-reliance and planning go hand in hand.

Correlation between Borrowing and Planning

Hn4: The relationship between borrowing and planning is not particularly strong.

Hn5: The relationship between borrowing and planning is quite strong.

Table 4: Borrowing and Planning

		Borrowing	Planning
Borrowing	Correlation	1	0.378**
	Sig.		.000
	Respondents(N)	209	209
Planning	Correlation	0.378**	1
	Sig.	.000	
	Respondents(N)	209	209

According to table 4, the coefficient of connection between borrowing and planning is 0.378. It indicates that two variables have a positive association. At the 1% level of significance, the found correlation coefficient is quite significant. As a result, the alternative hypothesis is accepted and the null hypothesis is rejected. It makes sense to believe that borrowing and planning are interrelated. This suggests that these two sets of data have a strong relationship with one another.

FINDINGS

The correlation test reveals a positive coefficient of association between the variables borrowing and planning, borrowing and saving, saving and self-dependence, and self-dependence and saving. At the 1% level, the obtained coefficient of correlation is significant. As a result, the alternative theory is accepted and the null hypothesis is refuted. Saving and borrowing, self-reliance and planning, saving and self-reliance, and borrowing and planning are all somehow related. This suggests that these two sets of data have a strong relationship with one another.

- A one-way ANOVA test across the education component found that borrowing and planning differ considerably across educational levels. There are no discernible distinctions across education levels when it comes to saving, investing, and being self-sufficient.
- In terms of borrowing, investing, and planning, the age groups differ significantly, according to a one-way ANOVA test across the age factor. There are no appreciable differences across age groups in terms of independence and saving.

SUGGESTION

The government should make the necessary efforts, as should non-governmental organisations (NGOs). Aim to increase financial literacy and inform consumers of the most effective financial investment options. Additionally, it was discovered that the respondents weren't keeping accurate financial records. The rural and semi-urban areas should receive in-depth instruction and workshops on how to maintain household accounts for better financial management. Insurance has been identified as a preferred financial instrument among Karnataka's non-working women. The responders should also be made aware of several more highly advantageous financial products, such as mutual funds, KVP, post office savings plans, and others, so that they can benefit

CONCLUSION

Everyone now has access to a plethora of knowledge in a variety of academic subjects thanks to the information technology era, enabling people to enhance their quality of life. In recent years, emerging nations like India have placed an increasing emphasis on the empowerment and education of women. Independent of whether or not they are working, financial literacy is a significant determinant in a nation's economic growth, especially among women. The pace of economic growth will increase with improved financial knowledge and a favourable outlook on financial planning and investment. This study demonstrated how financial literacy affects non-working women's financial planning in order to prevent unfavourable outcomes as a result of today's more challenging economic and domestic conditions.

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Organizational Effectiveness in the Spinning Mills of Puducherry Union Territory - A Study

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ABSTRACT

Organization Effectiveness is the concept of how effective an organisation is achieving its goals. Every employee in company contributes to organizational effectiveness. This study compared private, public and cooperative sector spinning mills in the Puducherry Union territory on their organizational Effectiveness and organizational structure. The study is based on the survey method, the data is collected through questionnaire from the employees in the spinning mills. A sample of 75 respondents was taken from employees of spinning mills. The statistical tools like correlation and predictive statistics helped to analyze the results. The study found that spinning mills generally fell in the middle range of effectiveness. There is a significant difference in the organizational effectiveness among private, public and cooperative sector spinning mills in the Puducherry Union Territory.

KEYWORDS : *Organizational effectiveness, Spinning mills, Private, Public and cooperative.*

INTRODUCTION

Textile industry in India is the largest industry in the world next to agriculture and Indian textile industry is one of the largest in the world next to China. Nearly 28 per cent of the foreign exchange earnings are on account of export of textiles and clothing alone. The textile and clothing sector contributes about 14 per cent to the industry production and 3 per cent to the GDP of the country. Also this industry accounts for 21 per cent of the total employment generated in our economy. Around 35 million people are directly employed in the textile manufacturing activities (Indian Textile Industry, 2016). The textile industry can be classified into two categories i.e., the organised sector and the unorganised sector. The organised sector of the textile industry represents the mills, it could be a spinning mill or a composite mills. The decentralised sector has been found to be engaged mainly in the weaving activity which make dependent on organised sector for their yarn production.

ORGANISATIONAL EFFECTIVENESS

There is no agreement on a definition for organisational effectiveness. The numbers of definitions vary with the number of authors who have been pre-occupied with the concepts. In addition to the different definitions of organisational effectiveness there is a tendency to view effectiveness as

either one dimensional or multi-dimensional. Society has tried to organise human activity to yield the highest output. Organisations are continually reporting results for which they are held accountable, traditionally by owners or stock-holders and more by other interested groups (Adam Smith).

Effectiveness is generally defined as the degree to which an organisation realises its goals (Amitai Etzioni, 1964). In our present day living, organisation must be effective as they are indispensable. But the questions before us are; what do we mean by organisational effectiveness? How to measure organisational effectiveness and what are those factors/dimensions which determine organisation effectiveness? Sometimes the words productivity, efficiency and effectiveness are used interchangeably. But, there is a substantial difference in these words.

STATEMENT OF THE PROBLEM

Organisational effectiveness or effectiveness of organisation play a vital role in every organisation. Generally organisation realised its goals for their effectiveness. Growth and profitability are the important tools for measuring the effectiveness in an organisation. Also, the multiple criteria approach is more helpful for the assessment of organisation effectiveness. There are three types of business organisations in the industrial setup of our country, namely; public

ownership organisation, private ownership organisation and cooperative ownership organisation. These three types of organisations differ in the matter of objectives, structure, and pattern of ownership, financing and management. The public sectors are wholly or substantially owned by the Government with a focus on social welfare. Private sector is the oldest and the basic moto of making profit by all means. The exploitation and inequality are increasing day by day in the private sector. The cooperative sector have come into existence only after independence. They are fully owned and financed by the members with prime objectives have to provide satisfactory service to them. These three types of organisations seems to be different in the matter of organisational structures, namely; the public and cooperative sectors appear more formalised and centralised, whereas the private sector does not seems to be so.

OBJECTIVES OF THE STUDY

1. To study the organisational structure of public sector, private sector and cooperative sector spinning mills in the Puducherry Union Territory and to find out the relationship between managerial role and organisational structure
2. To measure and compare the organisational effectiveness among Public sector vs. Private Sector, Public Sector vs. Cooperative Sector and private Sector vs. Cooperative Sector Spinning Mills in the Puducherry Union Territory.

METHODOLOGY

The study is comparative and correlation study based on survey method and the unit of analysis is organisational effectiveness in Public, Private and Cooperative Sector Spinning Mills of Puducherry Union Territory. Comparison from each other among three sector spinning mills. i.e., in between Public Sector Spinning Mills vs. Private Sector Spinning Mills, Public Sector Spinning Mills vs Cooperative Sector Spinning Mills and Private Sector Spinning Mills vs. Cooperative Sector Spinning Mills.

Also, correlation coefficient among organisational effectiveness on overall as well as factor-wise and its various factors centralisation overall and its various factors formalisation overall as well as factor wise are computed for spinning mills as a whole and its three sectors, viz, public, private and cooperative.

The study is used both primary source of data and secondary sources of data. Primary data pertaining to organisational structure, managerial role and to measure behavioural dimensions of organisational effectiveness, organisational structure variables, namely, viz; formalisation

and centralisation were collected by using structured questionnaire. The secondary sources of data used in this study consisted of information from published books, journals, magazines, articles, doctoral thesis, byelaws and websites.

MAJOR FINDINGS ASSESSMENT AND COMPARISON OF ORGANISATIONAL EFFECTIVENESS

Organizational effectiveness has been measured in terms our eight behavioural dimensions, that is how managers rate their organization on these dimensions. Assessment of organizational effectiveness in terms of behavioural dimensions is relatively a new phenomenon. It has traditionally been measured in terms of objective variable, such as profitability, growth and productivity. How well the business performs is the outcome of an effective organizational effectiveness. So, how do businesses achieve sustainable organizational effectiveness? As stated, a key element is to align employees with the company's strategy by (1) helping them to understand the part they play in achieving success, and (2) engaging employees in their jobs and with the organization.

Strategy alignment is achieved through a "fit-for purpose" structure, capable leadership, and effective people systems and culture. Integrating efforts across these areas will lead to more highly engaged employees who are willing and capable of helping the organization to achieve its goals. However, sustainable organizational effectiveness requires that attention be paid to all of these elements-focusing attention on just one without the others will not deliver long-term engagement.

ORGANISATIONAL EFFECTIVENESS IN SPINNING MILLS OF PUDUCHERRY UNION TERRITORY

The assessment of organizational effectiveness is very important step in the development of an organization. Its importance in designing and establishing an effective organization has been discussed by scholars. In this line, the present chapter is undertaken as part of present research work. To assess the organizational effectiveness of spinning mills in Puducherry, 24 items, covering its various aspects such as goals and objectives, utilization of resources, employees' team spirit, cohesiveness, interpersonal climate, working environment, coordination & integration, etc, are included in the questionnaire. The five-point Likert scale, namely "1" for "strongly disagree" to "5" for "strongly agree" and "2" for "disagree", "3" for "no opinion" (neither agree nor disagree) and "4" for "agree in between, is used to obtain the opinion of

the respondents about the above organizational effectiveness measurement items.

To evaluate the internal consistency of the 24 items in the scale measuring organizational effectiveness, the opinion data are subjected to reliability / item analysis to calculate Cronbach's alpha reliability coefficient. After ascertaining the internal consistency of the items in the scale, the data are then subjected to Principal Component Factor analysis with Varimax rotation to identify the underlying dimensions (factors) of organizational effectiveness in the spinning mills in Puducherry state. Then, the scores for each dimension are calculated by averaging the opinion data of each item which is highly loaded in that dimension. The scores thus obtained for each dimension then compared across groups by sector, level of management and socioeconomic characteristics of the managerial employees in spinning mills.

The collective impact of socio-economic characteristics on the perceived status of organizational effectiveness in spinning mills are analyzed using 't'-test and One way ANOVA 'F'-test. It is apparent from the examination of "item to total correlation", that the correlation of all 24 items with their total sum score varies from 0.3005 (Item 2) to 0.6262 (Item 24), indicating sufficient positive correlation values of at least 0.30 (Table in Appendix). As there is sufficient correlation between each item and total sum score, all these items in the scale are considered to be internally consistent with each other in measuring organizational effectiveness and the data against these 24 items can be retained and used for further analysis. It is further apparent from table that the Cronbach's alpha reliability coefficient is 0.8788, indicating that the degree of internal consistency among 24 items in the scale measuring organizational effectiveness in Spinning mills of Puducherry Union Territory has been excellent.

As the scale items measuring organizational effectiveness are highly reliable and to identify the underlying dimensions of organizational effectiveness, the data are subjected to principal component factor analysis with varimax rotation. The results of factor analysis, such as eigenvalue and explained variance of each factor and factor loadings of each item with valid factors are shown in Appendix. The initial eigenvalues that is eigenvalues before varimax rotation, for first eight factors are above one, indicating that these factors are important factors underlying organizational effectiveness.

The eigenvalue for first, second, third, fourth, fifth, sixth, seventh and eight factors is 6.63, 2.42, 2.26, 1.73, 1.67, 1.44, 1.21 and 1.12 with explained variance of 27.64 per cent, 10.10 per cent, 9.43 per cent, 7.20 per cent, 6.94 per cent, 5.98 per cent, 5.05 per cent and 4.66 per cent in the actual data set before varimax rotation respectively. All the above eight

factors together possess 77.02 per cent of the characteristics of the actual data pertaining to organizational effectiveness.

Table 1: Plots of Eigen Values for Organisational Effectiveness Dimensions

Value	Number of Eigen Values
6.63	27.64 per cent
2.42	10.00 per cent
2.26	9.43 per cent
1.73	7.20 per cent
1.67	6.94 per cent
1.44	5.98 per cent
1.21	5.05 per cent
1.12	4.66 per cent

From the above table it can be understood eight factors that the value declined from 6.43 to 1.12. The number of Eigen values also decreased from 27.64 per cent to 4.66 percent.

ORGANIZATIONAL EFFECTIVENESS IN SPINNING MILLS COMPARISON BY SECTOR

Table presents the results of one way ANOVA comparing the perceived mean scores of the managerial employees from private, public and co-operative sector spinning mills.

Table 2: Sector Wise Comparison of Organizational Effectiveness on Spinning Mills

Organizational Effectiveness Dimensions	Sector			F value
	Private (n=26)	Public (n=26)	Cooperative (n=23)	
Setting Goals and Objectives	3.88 (0.48)	3.40 (0.82)	3.13 (1.06)	5.49***
Utilization of resources	3.51 (0.44)	3.15 (0.74)	2.70 (0.69)	10.07**
Work Environment	3.21 (0.45)	3.33 (0.60)	3.12 (0.82)	0.73
Coordination and Integration	3.67 (0.55)	3.71 (0.87)	3.28 (0.86)	2.26
Employees Cohesiveness	3.19 (0.56)	3.04 (0.76)	3.05 (0.66)	0.42
Team Orientation	3.60 (0.42)	3.35 (0.64)	3.09 (0.80)	3.97**
Adapting to external conditions	3.13 (0.76)	3.17 (0.81)	3.48 (0.91)	1.25
Striving for Accomplishment	3.77 (0.31)	3.46 (0.65)	3.14 (0.74)	6.84***

Figures in brackets are standard deviation.

Significant at 5% level. *Significant at 1% level.

The above table shows that the perceived mean scores are above three for all sector groups in respect of all aspects of organizational effectiveness except for cooperative

spinning mills employees with regard to “Utilization of resources” (Mean=2.70) The F value, obtained for the difference in group means, is significant at 1 per cent level for “Setting Goals and Objectives” ($F=5.49$, $p<0.01$) “Utilization of resources” ($F=10.07$, $p<0.01$) and “Striving for accomplishment” ($F=6.84$, $p<0.01$) and significant at 5 per cent level for “Team Orientation” ($F=3.97$, $p<0.05$). From this picture, it is evident that there is significant difference in the organizational effectiveness in respect of setting goals and objectives, utilizing resources, striving for accomplishment of goals and objectives, and team orientation across spinning mills by sectors in Puducherry.

It is concluded that there is significant difference in the organizational effectiveness in respect of setting goals and objectives, utilization of resources, team orientation and striving for accomplishment of goals and objectives among private, public and co-operative sector spinning mills in the U.T. of Puducherry.

ORGANISATIONAL EFFECTIVENESS AND SOCIO-ECONOMIC CHARACTERISTICS OF MANAGERS

In order to know whether the perceived organizational effectiveness is related to the respondents' socio-economic characteristics or not, the perceived mean scores are compared across respondent groups by age, marital status, education, monthly income, length of service, present position, experience in present position, functions of management and levels of management using parametric t-test (two group comparison) and F-test (more than two groups comparison). The results of the analysis and discussion of the results are shown hereunder.

Table 3: Comparison of Organizational Effectiveness by Managers' Age

Organizational Effectiveness Dimensions	Age (in Years)			F value
	Up to 35 (n=19)	36-45 (n=21)	Above 45 (n=35)	
Setting Goals and Objectives	3.74 (0.93)	3.45 (0.92)	3.37 (0.77)	1.14
Utilization of resources	3.13 (0.67)	3.17 (0.69)	3.12 (0.76)	0.03
Work Environment	2.96 (0.65)	3.27 (0.67)	3.33 (0.58)	2.24
Coordination and Integration	3.55 (0.69)	3.33 (0.66)	3.71 (0.89)	1.57
Employees Cohesiveness	2.83 (0.49)	3.35 (0.56)	3.09 (0.75)	3.25*
Team Orientation	3.30 (0.77)	3.38 (0.61)	3.36 (0.63)	0.08
Adapting to external conditions	3.11 (0.91)	3.40 (0.80)	3.24 (0.81)	0.65
Striving for Accomplishment	3.42 (0.67)	3.49 (0.66)	3.49 (0.62)	0.08

Figures in brackets are standard deviation. **Significant at 5% level

The calculated F values for the difference in mean perception scores across age groups are insignificant for all except “employees cohesiveness”. For employees cohesiveness, the F value of 3.25 is significant at 5 per cent level, in turn indicating that effectiveness of organization in respect of employees cohesiveness is significantly associated with age of the managerial employees.

It is concluded that effectiveness of organization in respect of employees cohesiveness is significantly associated with age of the managerial employees.

Table 4: Comparison of Organizational Effectiveness in Spinning Mills by Managers' Marital Status

Organizational Effectiveness Dimensions	Marital Status				t-value
	Unmarried (n=8)		Married (n=67)		
	Mean	SD	Mean	SD	
Setting Goals and Objectives	3.88	0.35	3.44	0.89	1.36
Utilization of resources	3.38	0.44	3.11	0.73	1.01
Work Environment	3.21	0.59	3.22	0.64	0.07
Coordination and Integration	3.81	0.59	3.54	0.80	0.94
Employees Cohesiveness	2.88	0.42	3.12	0.68	1.01
Team Orientation	3.50	0.63	3.34	0.66	0.67
Adapting to external conditions	3.25	1.07	3.25	0.80	0.01
Striving for Accomplishment	3.71	0.38	3.44	0.65	1.12

Figures in brackets are standard deviation.

An examination of the table shows that the employees with unmarried status have perceived organizational effectiveness with regard to “Setting goals and objectives” (Mean=3.88), “Utilization resources” (Mean=3.38), “Coordination and Integration” (Mean=3.81), “Team orientation” (Mean=3.50) and “Striving for accomplishment” (Mean=3.71) as high whereas married group have highly viewed the “Employee cohesiveness” (Mean=3.12) compared to their respective counterparts. But from the examination of t-values, which are insignificant for all factors, it is apparent that the organizational effectiveness is not affected by the marital status. It is concluded that organizational effectiveness in spinning mills is not affected by the marital status.

CONCLUSION

The status of organizational effectiveness has been evaluated. There are eight dimensions of organizational effectiveness namely, Setting Goals and Objectives, Utilization of resources, Work Environment, Co-ordination and Integration. Employees Cohesiveness, Team Orientation, Adapting to

external conditions and Striving for Accomplishment of Goals and Objectives

It is identified that the spinning mills in Puducherry are effective in "Co-ordination and Integration" followed by "Setting Goals and objectives", "Striving for accomplishment", "Team orientation", "Adapting to external conditions", "Work environment", and "Utilization of resources" whereas it is neither effective nor ineffective in respect of "Employee cohesiveness", "Work environment", and "Utilization of resources" whereas it is neither effective nor ineffective in respect of "Employee cohesiveness". There is significant difference in the organizational effectiveness in respect of setting goals and objectives, utilisation of resources, team orientation and striving for accomplishment of goals and objectives among private, public, and co-operative sector spinning mills.

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Integrating Data Science and Machine Learning in the Internet of Things (IoT) Ecosystem for Smart Decision-Making

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ABSTRACT

The Internet of Things (IoT) has revolutionized a variety of industries by facilitating the real-time collection of data from connected devices. Nevertheless, the management and analysis of enormous quantities of IoT-generated data necessitate sophisticated methodologies, including data science and machine learning. This paper investigates the ways in which data science and machine learning can be integrated to improve IoT applications. The primary objectives are to optimize data processing, predictive analytics, and intelligent decision-making. The study also addresses challenges such as data security, model efficiency, and computational constraints, and it suggests solutions to improve the performance and scalability of IoT-based systems.

KEYWORDS : *Internet of things, Data science, Machine learning, Predictive analytics, Smart decision-making, Data security, Computational efficiency.*

INTRODUCTION

Linking billions of things, the Internet of Things (IoT) has emerged into a game-changing technology enabling seamlessly integrated data collecting, transmission, and analysis. Businesses are spending more and more on Internet of Things (IoT) enabled solutions, so the ability to derive relevant insights from vast amounts of sensor-generated data has become quite crucial [1].

Unlocking the full potential of Internet of Things (IoT) systems depends critically on the combination of data science and machine learning (ML). From smart cities to healthcare to industrial automation to energy management, this integration guarantees optimal decision-making, predictive analytics, and automation in many different fields.

The proliferation of Internet of Things devices has led to an exponential increase in the volume of created data. Recent studies show that by 2025 the number of Internet of Things devices connected to the internet would have exceeded 75

billion, producing an annual creation of 79.4 zettabytes of data. Along with disadvantages, the growing data volume presents several opportunities. On the one hand, real-time analytics enables companies to provide more tailored services, raise their operational efficiency, and enhance their degree of security [2]. Conversely, conventional data processing systems struggle with the sheer volume, speed, and variety of data produced by the Internet of Things (IoT). Thus, one must employ advanced data science and machine learning techniques.

Machine learning algorithms might help to more effectively handle and analyse data from the Internet of Things (IoT) by letting systems learn from past trends and create intelligent predictions. These abilities are very beneficial for applications such predictive maintenance, anomaly detection, and energy optimisation where real-time decision-making is of great relevance [3]. Moreover, two practical approaches to address computational constraints are edge computing and federated learning. These technologies guarantee that Internet of Things

apps keep being scalable, effective, and a privacy protection tool for consumers.

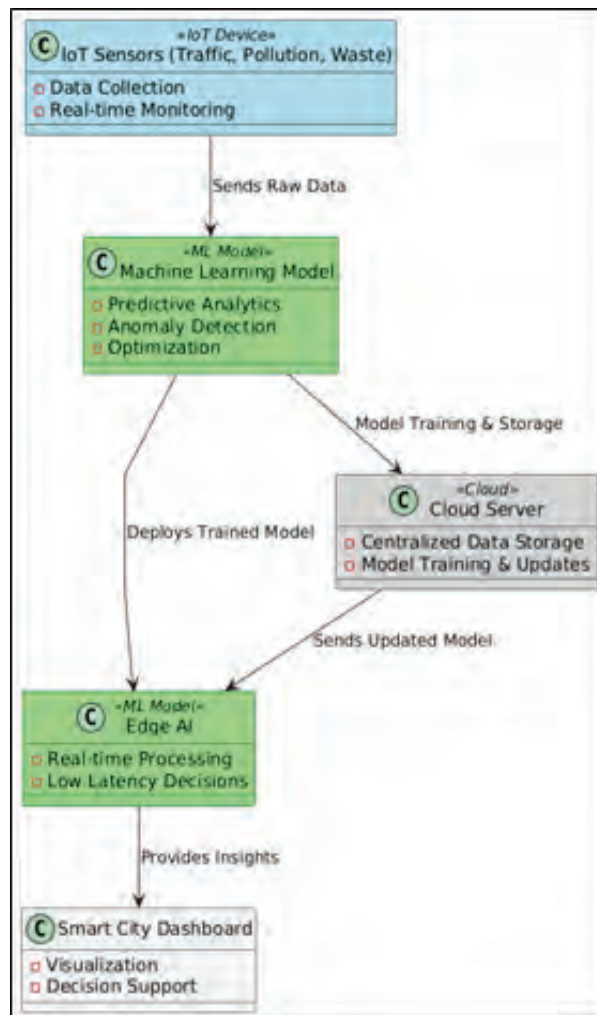


Fig. 1. Machine Learning-Driven IoT Applications in a Smart City

ROLE OF DATA SCIENCE IN IOT

Because it allows people to gather, analyse, and make choices in real time, the Internet of Things (IoT) is now a major instrument in many different disciplines. Conversely, the massive volume of data IoT devices generate makes storage, analysis, and sense of meaning difficult. Data science is really crucial in order to address these challenges. It converts IoT data into concepts that may be used by means of statistical approaches, data preparation strategies, and machine learning algorithms [4]. Data science's inclusion into IoT is transforming areas like healthcare, smart cities, industrial robots, and agriculture by making them more safe, efficient, and future-predicting capable.

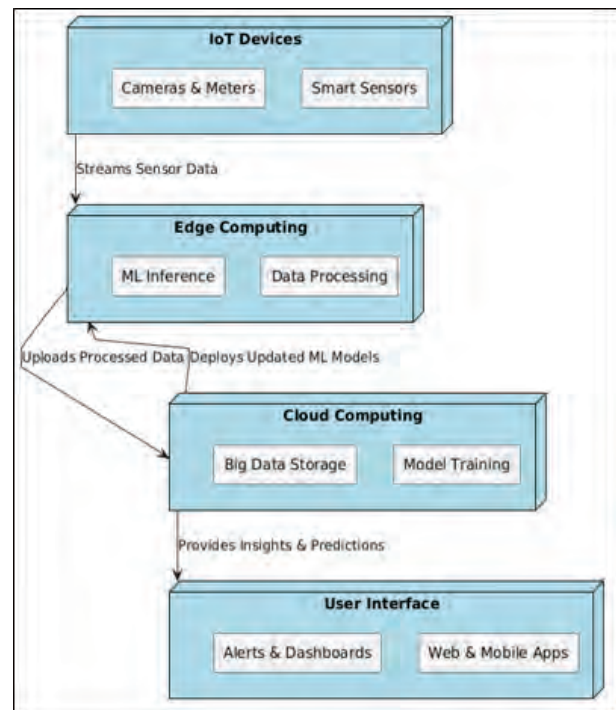


Fig. 2. Data Science in IoT

Data science in the Internet of Things depends much on data cleaning and preparation. IoT devices continuously communicate both ordered and unstructured data, which often contains noise, missing values, and mistakes. IoT packages are guaranteed to be correct and reliable by means of records training strategies like data normalisation, lacking cost estimate, and noise reduction. those strategies knock out errors and serve to make information kinds more consistent in order that they will be used for additional observe. IoT programs may also offer erroneous predictions and conclusions once they forget about right records preparation.

still some other quintessential issue of data technological know-how in the IoT is feature engineering. this is the selection and amendment of valuable traits from unprocessed information to enhance fashions [5]. functions engineering strategies like dimensionality reduction, principal component analysis (PCA), and function selection equipment assist IoT information analysis to be improved. IoT devices produce lots of inappropriate and redundant statistics, so selecting the ideal characteristics is rather quintessential for simplifying calculations and perception of predictive fashions. smart town programs, for instance, may utilise sensor records from traffic cameras and environmental monitors to become aware of patterns in pollutants and visitors, therefore guiding municipal officers' moves depending on such records.

Exploratory data analysis (EDA) is yet another crucial component of data science in IoT. Part of EDA involves visualising and summarising data to identify patterns, connections, and anomalies. We find the patterns in IoT data using tools such as histograms, scatter graphs, correlation matrices, and grouping techniques [6]. Early machine failure in industrial IoT applications may be found using EDA by examining sensor data concerning temperature, vibration, and pressure. Predictive maintenance techniques allow manufacturers to detect issues in real time, therefore reducing downtime and increasing productivity.

Combining IoT with data science also makes predictive analytics feasible, which is necessary to project future events using previous data. Among the predictive modelling techniques that let IoT systems prepare for future failures, spend energy more wisely, and better allocate resources are linear regression, decision trees, support vector machines (SVM), and deep learning. By examining historical use, predictive analytics can forecast the required amount of power in smart grid applications. This helps energy suppliers reduce waste and better distribute their electricity. Prediction algorithms in the same vein may examine smart device data in healthcare IoT to identify early indicators of health issues such as diabetes and heart disease. This enables medical practitioners to respond before the issue escalates.

Data science is also very important for real-time analytics, which helps IoT programs grab and respond to data immediately. In the Internet of Things (IoT), where choices must be taken immediately, conventional batch processing techniques can prove insufficient. Real-time data collecting and analysis are made possible by stream processing systems such as Apache Kafka, Apache Flink, and Spark Streaming. IoT systems so may rapidly identify issues and initiate automated responses. Real-time analytics in self-driving vehicle systems combine LiDAR sensor, GPS module, and camera data to determine routing decisions in a few of seconds. This maintains passenger safety and streamlines route planning.

Another vital use of data science in the Internet of Things is anomaly detection. This entails looking for patterns or actions defying convention. Many applications keep IoT devices secure, monitor industries, and identify frauds using anomaly detection techniques such as isolation forests, one-class SVM, and recurrent neural networks (RNNs). Anomaly detection systems in cybersecurity, for example, might examine network traffic data to identify odd activity such as malware assaults, data breaches, or attempts at access without authorisation. Anomaly detection in industrial IoT enables monitoring of machine performance and early issue discovery. This makes operations more efficient and reduces

the repair costs.

In Internet of Things (IoT) applications, data science also facilitates aggregation and division of data. This is particularly useful in tracking traffic, observing behaviour, and experiencing the surroundings. IoT data may be grouped with comparable patterns using k-means, DBSCAN, and hierarchical clustering among other techniques. This helps businesses to identify trends and enhance their offerings in line with them [8]. Clustering, for instance, may enable smart retail applications to group consumers according to purchase behaviour, therefore allowing businesses to provide tailored offers and recommendations. Clustering allows one to examine data from air quality sensors in environmental tracking and categorise locations according to degree of pollution. This guides legislators in their activities.

Reinforcement learning—which helps IoT systems evolve and grow better over time by constantly learning new things—also incorporates data science. Deep Q-Networks (DQN) and Policy Gradient Methods are increasingly being employed in smart home control, robotics, and energy management reinforcement learning contexts. Smart homes learn from what people like and dynamically modify the temperature settings to maximise their heating, ventilation, and air conditioning (HVAC) systems [9]. Reinforcement learning helps robots in robotics find out the optimum methods to move depending on real-time sensor inputs, hence improving robotic process automation.

Data science serves purposes beyond the technical ones. Managing privacy and security concerns in IoT communities is also quite crucial. IoT devices gather a lot of private and sensitive data, hence security, access control, and data storage must be all secure. IoT applications may examine data while safeguarding privacy thanks to new techniques like homomorphic encryption, differential privacy, and collaborative learning. Particularly federated learning helps IoT devices train machine learning models jointly without forwarding raw data to central computers [10]. This reduces data breaches risk and facilitates following GDPR and CCPA data protection regulations.

Furthermore very crucial for the size and applicability of IoT systems are data science approaches. IoT networks must find better methods to store, minimise, and access data as they expand in order to keep up with the growing volume. Edge computing solutions and cloud computing are becoming very essential for managing vast IoT projects. Edge computing allows IoT devices to analyse data locally, therefore reducing latency and internet use unlike cloud systems, which store and process data centrally [11]. IoT applications increasingly rely on hybrid models combining cloud and edge computing

to get the ideal combination of speed, affordability, and adaptability.

Data science is also very important for enhancing operations and the supply chain via IoT-based monitoring and analytics. Demand prediction models and predictive analytics enable companies better regulate their supplies, save expenses, and increase supply accuracy. IoT tracks goods using GPS in real time, while machine learning algorithms examine prior shipping data to identify the optimal paths and minimise delays. Warehouse automation technologies simplify inventory control by use of computer vision and deep learning. This guarantees a flawless running of the supply chain.

MACHINE LEARNING APPLICATIONS IN IOT

Anomaly Detection

Anomaly detection in IoT uses ML algorithms to become aware of irregular patterns or deviations from predicted behavior in sensor statistics. This software is indispensable in areas which includes cybersecurity, fraud detection, and business monitoring. ML techniques such as isolation forests, one-elegance SVM, and autoencoders stumble on anomalies through getting to know the normal behavior of a gadget and flagging deviations. as an example, in network safety, ML-pushed IoT solutions examine community visitors in clever homes and businesses to hit upon unusual get entry to styles, preventing cyberattacks. Similarly, in smart grids, anomaly detection enables stumble on energy theft or electricity failures, ensuring strong and green strength distribution [12].

ENERGY OPTIMIZATION

Machine Learning drastically improves strength control in IoT programs, particularly in smart homes, commercial centers, and clever grids. ML models examine power intake styles and optimize power usage with the aid of dynamically adjusting home equipment and gadgets primarily based on call for. Reinforcement learning and deep learning strategies are generally used to make actual-time energy-saving choices. as an instance, in smart homes, ML-primarily based IoT systems examine user behavior and automatically alter lights, HVAC, and other electrical devices to reduce electricity waste [13]. In statistics centers, ML algorithms optimize cooling systems, decreasing energy consumption while maintaining efficiency.

Healthcare Monitoring

IoT-enabled wearable devices and sensors generate real-time health information, which ML algorithms examine to offer insights right into a patient's fitness fame. ML applications in healthcare IoT consist of early ailment detection, personalized

remedy suggestions, and faraway patient tracking. strategies such as decision bushes, support vector machines (SVM), and deep neural networks procedure information from wearables, smartwatches, and biosensors to discover anomalies together with abnormal heartbeats or oxygen saturation drops. as an example, ML models in clever hospitals examine ECG information to expect ability cardiac events, allowing doctors to interfere early and prevent medical emergencies [14].

Smart Traffic Management

In smart cities, IoT sensors collect information from visitors cameras, GPS, and street sensors to optimize visitors glide and decrease congestion. ML models use this statistics to are expecting site visitors styles, stumble on congestion hotspots, and suggest alternative routes in actual time. Deep mastering fashions together with Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs) analyze video feeds to stumble on injuries, rule violations, and pedestrian movements. as an instance, in smart transportation systems, ML-powered IoT programs dynamically manage site visitors lighting based totally on actual-time congestion records, reducing waiting times and improving road performance [15].

SMART AGRICULTURE

Machine learning enhances precision farming through studying IoT-generated data from soil sensors, climate stations, and drones to optimize agricultural practices. ML models predict soil moisture tiers, pest infestations, and crop fitness to assist farmers make records-driven selections. Strategies such as random forests, regression fashions, and deep getting to know are used to screen weather situations, soil vitamins, and irrigation degrees, ensuring optimum crop yields [16]. for example, AI-powered drones ready with ML fashions analyze crop pix to come across illnesses early, permitting farmers to take timely corrective actions and improve productivity.

SUPPLY CHAIN OPTIMIZATION

Machine learning in IoT-driven supply chain management complements inventory monitoring, demand forecasting, and logistics planning. IoT sensors monitor shipment conditions, warehouse storage, and fleet management, while ML models analyze historical data to are expecting call for fluctuations and optimize inventory levels. Algorithms which include gradient boosting, time-collection forecasting, and reinforcement studying optimize delivery routes and decrease transportation costs. for instance, in logistics groups, ML-powered IoT answers song vehicle locations and weather conditions to dynamically reroute shipments, ensuring timely deliveries and minimizing disruptions.

ENVIRONMENTAL MONITORING

ML-powered IoT programs display air quality, water pollutants, and weather conditions to decorate environmental safety and sustainability. IoT sensors deployed in industrial zones and concrete regions gather information on carbon emissions, temperature, and humidity, which ML models examine to are expecting environmental dangers. Clustering algorithms, regression fashions, and deep mastering permit authorities to take preventive movements against wildfires, floods, and pollution spikes. as an instance, ML fashions in smart cities examine air pollutants facts to forecast smog degrees, supporting government put into effect regulations and improve public fitness policies.

INDUSTRIAL AUTOMATION (INDUSTRY 4.0)

Machine learning is transforming smart production by means of enabling automatic nice manipulate, robotics integration, and manufacturing process optimization. IoT sensors embedded in manufacturing unit system and manufacturing strains generate actual-time information on system overall performance, product defects, and operational performance. ML fashions which includes reinforcement studying, deep Q-networks (DQN), and unsupervised clustering automate decision-making and optimize assembly strains. for instance, in car manufacturing, ML-powered IoT systems discover faulty elements using computer imaginative and prescient algorithms, lowering waste and improving product excellent.

SMART HOME AUTOMATION

IoT-enabled clever home gadgets, including voice assistants, protection cameras, and thermostats, use ML to enhance automation and personalization. ML models analyze person behavior, occupancy styles, and environmental situations to make shrewd changes. Neural networks and reinforcement mastering assist clever assistants research from person picks to offer customized tips for lights, temperature manage, and safety settings. for instance, ML-driven clever thermostats research citizens' schedules and adjust room temperatures dynamically, optimizing strength intake at the same time as maintaining comfort.

FRAUD DETECTION IN IOT TRANSACTIONS

IoT-enabled clever home gadgets, including voice assistants, protection cameras, and thermostats, use ML to enhance automation and personalization. ML models analyze person behavior, occupancy styles, and environmental situations to make shrewd changes. Neural networks and reinforcement

mastering assist clever assistants research from person picks to offer customized tips for lights, temperature manage, and safety settings. for instance, ML-driven clever thermostats research citizens' schedules and adjust room temperatures dynamically, optimizing strength intake at the same time as maintaining comfort.

FEDERATED LEARNING FOR PRIVACY-PRESERVING IOT

Traditional ML models require centralized statistics series, which increases privateness issues in IoT applications. Federated learning (FL) permits allotted model training without delay on IoT gadgets, ensuring facts privacy and protection. ML fashions which includes Google's Federated Averaging (FedAvg) algorithm allow a couple of IoT gadgets to collaboratively train ML fashions barring sharing raw records. This method is especially beneficial in healthcare, clever houses, and industrial IoT, wherein sensitive facts have to stay personal. As an example, smart wearable devices use FL to enhance personalised health insights besides compromising affected person information privateness.

Table 1. Machine Learning Applications in IoT

Application	IoT Use Case	ML Techniques Used	Real-World Example
Predictive Maintenance	Prevent equipment failures by predicting maintenance needs	Time-series forecasting, LSTMs, anomaly detection	Manufacturing plants using predictive maintenance to reduce downtime
Anomaly Detection	Detect irregular patterns in sensor data to enhance security	Isolation forests, one-class SVM, autoencoders	Smart grids detecting electricity theft and preventing cyber threats
Energy Optimization	Optimize power consumption in smart grids and buildings	Reinforcement learning, deep learning, regression	Smart thermostats optimizing energy consumption based on user behavior
Healthcare Monitoring	Monitor patient health in real-time using wearable devices	Decision trees, SVM, deep neural networks	ECG-based ML models predicting cardiac events in smart hospitals

Smart Traffic Management	Analyze traffic patterns to reduce congestion and improve flow	CNNs, RNNs, deep learning-based video analysis	AI-powered traffic lights adjusting dynamically to congestion levels
Smart Agriculture	Use IoT sensors and ML models to improve crop yield and farming	Random forests, regression, deep learning	Drones detecting pest infestations and optimizing irrigation
Supply Chain Optimization	Enhance logistics, inventory tracking, and demand forecasting	Gradient boosting, time-series forecasting, reinforcement learning	ML-powered IoT tracking vehicle locations to reroute shipments dynamically
Environmental Monitoring	Monitor air quality, pollution, and environmental hazards	Clustering, regression, deep learning	Smart city initiatives forecasting pollution levels and improving regulations
Industrial Automation (Industry 4.0)	Automate manufacturing processes and optimize production lines	Deep Q-networks, reinforcement learning	Automotive manufacturing detecting defects in assembly lines
Smart Home Automation	Personalize automation in smart home devices	Neural networks, reinforcement learning	Smart assistants adjusting lighting and temperature preferences
Fraud Detection in IoT Transactions	Detect anomalies in financial transactions and IoT-based payments	Anomaly detection, supervised learning, adversarial networks	Mobile banking detecting suspicious transactions in IoT-based payments
Federated Learning for Privacy-Preserving IoT	Train ML models on IoT devices without sharing raw data	Federated averaging (FedAvg), decentralized learning	Wearable health devices improving personalized healthcare insights

CHALLENGES AND PROPOSED SOLUTIONS

Combining machine learning with IoT is one of the most important challenges related to information protection and

safety. IoT devices subject themselves to cyber attacks, statistics breaches, and unlawful get right of entry to because they transmit and acquire large volumes of private statistics. One may additionally reduce those dangers through quit-to- cease encryption, blockchain-based totally protection mechanisms, and shared gaining knowledge of those strategies reduce the want for centralised records maintaining, which may be a safety difficulty, and they hold information secure at the same time as it is being added and handled.

Nevertheless another critical difficulty are computational constraints. maximum IoT devices lack processing ability, memory, or battery life, therefore the usage of complicated ML fashions is hard. walking deep studying fashions on these devices with low sources may waste a number of time and create wonderful postpone. side computing, version quantisation, and TinyML among different techniques assist to clear up this mission. part synthetic brain gathers data immediately on IoT devices rather than thru the cloud. This lowers latency and increases computation efficiency.

Real-time processing is even any other essential mission. that is particularly true in fields such commercial automation, on line healthcare tracking, self-driving motors, and commercial automation, wherein even little selection-making mistakes may want to result in full-size issues. Traditional cloud-based computing introduces latency, so it cannot be used for IoT gadgets requiring actual-time operation. Because they manipulate facts closer to in which it originates, aspect AI, fog computing, and hybrid cloud-area structures may also help with this challenge. Consequently, responses are faster and central server dependency is lessened.

Data quality is a major issue as IoT devices may produce noise, mistakes, and missing figures. Bad data may lead ML models to provide erroneous predictions and lose accuracy. Complex data preparation techniques include data filtering, normalisation, feature engineering, and outlier identification can help you to resolve issue. Before data is input into machine learning models, these techniques assist clean and arrange it, hence increasing the dependability and speed of the models.

The scalability of machine learning models in IoT is even another significant challenge. As the number of linked IoT devices increases at exponential pace, managing, preserving, and analysing vast volumes of data is becoming more difficult. Standard centralised computer systems find it difficult to keep up with the rapid data flow. Large volumes of data can be swiftly handled using distributed computing solutions as Apache Spark, Kafka, and TensorFlow Distributed, so IoT programs may continue to expand unhindered.

Another crucial matter of consideration is energy use. Many IoT devices run on batteries, therefore applying ML

models requiring a lot of computation might rapidly run out their power, hence reducing their usable lifetime. One may employ lightweight machine learning frameworks, energy-efficient AI processors, hardware acceleration techniques like trimmed neural networks and optimised inference models to improve things. IoT devices can perform clever things using less power using these techniques.

In IoT systems, interoperability and standardisation are particularly challenging as various manufacturers apply diverse hardware designs, communication technologies, and data types. Combining and using ML models across many IoT networks is challenging without any criteria. Using common IoT communication technologies such as MQTT, CoAP, and 5G-enabled systems would help devices to exchange data and cooperate more easily, thus improving things together.

Integration of IoT with machine learning depends much on model training and changing. IoT devices operate in dynamically changing environments, hence ML models must be constantly modified to fit new data patterns and conditions. Constant education in centralised environments might, however, consume a lot of resources and take a lengthy period. Good choices include federated learning and incremental learning as they enable ML models be altered locally on IoT devices while only exchanging the most crucial model parameters with a central computer. This guarantees that education never ends without excessive internet use or compromising of privacy rights.

Another issue is that you have to acquire high-performance computer gear, cloud services, and data storage therefore implementing AI-driven IoT solutions costs a lot. Many small companies and organisations struggle with the expenses of installing sophisticated machine learning systems. Cheaper choices include open-source machine learning frameworks, cloud-based artificial intelligence solutions, hardware-optimized models that save computational costs while maintaining speed.

Table 2. Challenges and Proposed Solutions in Integrating Machine Learning with IoT

Challenges	Description	Proposed Solutions
Data Security and Privacy	IoT devices generate massive amounts of sensitive data, making them vulnerable to cyber threats and breaches.	Implement end-to-end encryption, blockchain-based security, and federated learning to enhance data privacy.
Computational Constraints	Many IoT devices have limited processing power, memory, and battery life, making it difficult to deploy ML models.	Use TinyML, quantized ML models, and edge computing to run ML algorithms efficiently on resource-constrained devices.

Real-time Processing	IoT applications, such as autonomous vehicles and healthcare monitoring, require low-latency decision-making.	Utilize edge AI, fog computing, and hybrid cloud-edge architectures to minimize delays.
Data Quality and Noise	IoT sensors often produce incomplete, noisy, or redundant data, affecting the accuracy of ML models.	Use data preprocessing techniques like filtering, normalization, and feature selection to clean and structure IoT data.
Scalability Issues	The increasing number of IoT devices generates huge data streams, creating challenges in handling large-scale ML models.	Deploy distributed computing frameworks like Apache Spark, Kafka, and TensorFlow Distributed to manage large-scale data.
Energy Consumption	Running ML models on IoT devices with limited battery life can drain power quickly.	Optimize ML models with lightweight architectures, such as pruned neural networks and low-power AI chips.
Interoperability and Standards	IoT devices from different manufacturers use diverse protocols, formats, and communication standards, creating compatibility issues.	Adopt standardized communication protocols such as MQTT, CoAP, and 5G-enabled IoT frameworks for seamless integration.
Model Training and Updating	IoT devices require continuous model retraining to adapt to evolving patterns and conditions.	Use federated learning and incremental learning techniques to update models without requiring centralized data collection.
Cost of Implementation	Deploying AI-driven IoT solutions often involves high infrastructure and hardware costs.	Use open-source ML frameworks, cloud-based ML solutions, and hardware-optimized AI models to reduce expenses.

CASE STUDY: SMART CITIES IMPLEMENTATION

With the rapid urbanization and growing populace density in cities global, conventional urban management methods are getting insufficient to cope with challenges which includes site visitors congestion, waste management, electricity consumption, and public protection. the integration of Internet of Things (IoT) and machine learning (ML) has revolutionized city infrastructure via allowing real-time information collection, clever automation, and predictive choice-making. clever towns leverage IoT-powered sensors and ML algorithms to enhance performance, sustainability, and usual first-class of life for citizens.

Smart cities set up IoT devices together with traffic cameras,

environmental sensors, clever meters, and related public infrastructure to accumulate massive amounts of statistics. system studying fashions then analyze this data to pick out patterns, hit upon anomalies, and offer intelligent insights that improve city operations. with the aid of implementing AI-driven automation, real-time analytics, and predictive modeling, urban administrations could make data-driven selections that optimize resource allocation and infrastructure performance.

Smart Traffic Management

One of the most considerable demanding situations in urban areas is visitors congestion, which leads to accelerated gasoline consumption, pollution, and lost productiveness. IoT-enabled visitors sensors, GPS statistics from automobiles, and CCTV cameras provide real-time site visitors records. machine gaining knowledge of algorithms, which includes deep gaining knowledge of-based totally pc vision and reinforcement mastering fashions, analyze this information to optimize site visitors' mild alerts, reroute visitors, and decrease congestion.

For example, in Singapore, the Intelligent Transport System (ITS) makes use of IoT and ML to predict traffic patterns, dynamically control traffic signals, and advocate alternative routes to drivers. As a result, travel time has been reduced, and average road efficiency has improved.

Waste Management Optimization

Inefficient waste collection and disposal make a contribution to environmental pollutants and increased municipal fees. smart cities use IoT-enabled waste boxes ready with sensors that display fill ranges and waste composition. ML algorithms analyze this facts to optimize garbage series schedules and allocate resources efficiently.

As an example, in Barcelona, Spain, the smart waste management device has advanced collection performance by using 20% thru AI-primarily based course optimization. ML-pushed analytics assist authorities expect waste technology developments and broaden sustainable waste discount rules.

Energy Efficiency and Smart Grids

Smart cities combine IoT-based clever meters and sensors to express strength consumption and beautify energy performance. ML models analyze energy usage patterns to optimize electricity distribution, demand reaction, and grid performance.

A gorgeous instance is Amsterdam's smart Grid assignment, which makes use of ML-powered predictive analytics to stability power deliver and demand dynamically. This reduces strength wastage and complements the aggregate of

renewable strength assets, making the town more sustainable and fee-green.

Public Safety and Crime Prevention

Making sure public safety is a top priority for smart towns. IoT-powered CCTV cameras, environmental sensors, and emergency response structures generate data that ML models examine to detect crook sports, are expecting incidents, and enhance emergency response times.

for instance, Chicago's Predictive Policing software uses AI-powered surveillance to research crime records and pick out excessive-hazard regions. The system has helped law enforcement installation sources proactively, lowering crime prices in focused places.

Future Directions

The integration of machine learning (ML) and the Internet of Things (IoT) is continuously evolving, enabling smarter, more autonomous systems. As new technologies emerge, future advancements will focus on enhancing computational efficiency, security, privacy, and real-time decision-making. Below are some of the most promising future directions in IoT-driven ML applications.

Edge AI for Real-Time Decision-Making

With the increasing need for real-time analytics, Edge AI is expected to play a crucial role in IoT deployments. Currently, most ML models rely on cloud computing, which introduces latency and increases bandwidth consumption. Edge AI enables ML models to run directly on IoT devices, reducing response times and ensuring immediate decision-making without requiring cloud connectivity. Advances in low-power AI chips, TinyML, and optimized neural networks will further enhance Edge AI applications in areas such as autonomous vehicles, industrial automation, and smart healthcare.

5G and IoT Synergy for High-Speed Communication

The introduction of 5G networks will revolutionize IoT by enhancing data transmission speeds, reducing latency, and increasing device connectivity. With ML-powered IoT applications requiring vast amounts of data for training and inference, 5G will facilitate seamless communication between IoT devices and cloud/edge servers. This will be particularly beneficial in applications such as smart cities, connected healthcare, and industrial robotics, where real-time data exchange is critical.

Blockchain for IoT Security and Data Integrity

As IoT ecosystems expand, data security and privacy concerns are becoming more significant. Blockchain technology offers decentralized authentication, secure data sharing, and tamper-

proof records, addressing key IoT security challenges. In future implementations, blockchain-powered smart contracts will help in securing IoT transactions, identity management, and device authentication, ensuring trustworthy AI-driven decision-making in IoT environments.

Federated Learning for Privacy-Preserving AI

Traditional ML models require centralized data collection, raising concerns about data privacy, security risks, and compliance with regulations like GDPR. Federated Learning (FL) is an emerging technique that enables IoT devices to collaboratively train ML models without sharing raw data. Instead of sending sensitive data to a central server, only model updates are shared, ensuring privacy while improving learning efficiency. FL is particularly relevant in healthcare, finance, and smart homes, where data sensitivity is high.

Quantum Computing for IoT Data Processing

IoT generates vast amounts of data that require complex computational processing. Traditional ML algorithms often struggle with handling such large datasets efficiently. Quantum computing has the potential to accelerate ML training, optimize predictive analytics, and improve anomaly detection in IoT systems. In the future, hybrid quantum-classical ML models will enable faster IoT-driven insights in applications such as weather forecasting, logistics optimization, and cryptographic security.

AI-Driven Cybersecurity for IoT Networks

With the increasing number of connected devices, IoT networks are becoming prime targets for cyberattacks, including malware, data breaches, and denial-of-service (DoS) attacks. Future advancements in AI-driven cybersecurity will enable IoT systems to detect, predict, and mitigate cyber threats in real time. ML techniques such as deep learning-based intrusion detection, anomaly detection, and automated threat response will play a critical role in enhancing IoT security.

The future of IoT and machine learning is ready to be more self-sufficient, impenetrable, and actual-time, driven via improvements in side AI, federated learning, knowledge of, 5G, blockchain, and quantum computing. As IoT ecosystems preserve to enlarge, addressing demanding situations together with privacy, computational constraints, and cybersecurity risks will be imperative for scalability and adoption. The synergy between AI-driven automation and IoT connectivity will redefine smart towns, healthcare, enterprise, and environmental sustainability, leading to clever, self-optimizing, and adaptive IoT answers inside the coming years.

CONCLUSION

The integration of Machine Learning (ML) and the Internet of Things (IoT) has considerably transformed numerous industries, enabling smart automation, predictive analytics, and actual-time selection-making. by leveraging IoT-generated data and applying ML algorithms, corporations and governments can beautify efficiency, protection, and sustainability throughout programs consisting of clever towns, healthcare, industrial automation, and electricity control. The potential of ML fashions to analyze great IoT datasets, discover anomalies, optimize operations, and forecast destiny developments has been established to be precious in developing information-driven smart structures. In spite of its advantages, the seamless integration of ML with IoT provides numerous demanding situations, including statistics safety dangers, computational constraints, strength intake, and interoperability issues. Addressing those issues calls for improvements in privateness-preserving AI strategies, lightweight ML fashions, and scalable cloud-side architectures. technologies along with aspect AI, federated studying, blockchain for safety, and 5G networks are rising as key enablers for the destiny of IoT-pushed ML programs, making sure real-time processing, data integrity, and value-effective deployments. looking in advance, the continuing evolution of AI-powered IoT will see the upward jab of self-mastering adaptive systems, virtual twins, bio-stimulated optimization techniques, and quantum computing for huge-scale information evaluation. As IoT ecosystems grow, the ability to broaden wise, self-reliant, and privateness-maintaining ML models will become necessary in shaping the following generation of clever infrastructure, enterprise, and public offerings. In conclusion, the synergy among ML and IoT will drive innovation across multiple domain names, improving the exceptional of life, sustainability, and monetary boom. At the same time as demanding situations remain, persisted research and technological improvements will ensure that IoT-enabled ML systems turn out to be more green, impervious, and scalable, paving the way for a future where wise decision-making and automation grow to be the norm in connected environments.

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Unleashing the Power of Data Science in the Insurance Industry

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ABSTRACT

Over the past few years, data science has completely reshaped industries across the board, and insurance is no exception. As the world becomes more digitally connected, insurance companies are increasingly relying on data to improve efficiency, better understand their customers, and manage risks more effectively. This paper looks at how data science is affecting the insurance industry, with a focus on things like predicting trends, spotting fraud, offering personalized prices, and keeping customers happy. By using tools like big data, machine learning, and AI, insurers are getting insights that help them make better decisions and stay competitive in a fast-moving world. It also touches on the challenges and ethical questions that come with all this, plus what the future might hold for data science in the industry.

KEYWORDS : Digital platforms, Data science, Insurance industry, Customer experience, Personalization, Trust.

INTRODUCTION

One of the fundamental pillars of the world economy, the insurance industry is also one of its oldest. It enables companies and individuals to protect themselves financially from unforeseen losses. However, the traditional methods associated with risk evaluation, customer relationship management, claims processing, and business interactions have become inefficient and dysfunctional in a world driven by technology. Nowadays, there is a growing reliance on data science and analytics, and insurance companies have started adopting them to transform their operations.

Data science is one of the fields which contributed to the digital revolution that most industries are undergoing today. It encompasses a range of scientific disciplines that involve the application of methodologies, algorithms, and systems to derive meaning and insights from clean and unclean data. In regard to insurances, the enablement of data science allows insurers to scrutinize the massive amounts of data stemming from policyholders, claims, business processes, and even entire market behavior. With its help, data analytics, machine learning (ML), and artificial intelligence (AI) enables better predictions and risk evaluation among insurers, improves pricing model accuracy, refines fraudulent activity detection, and the overall customer experience.

The focus of this paper will be on the transformative impact of data science on the insurance industry, its current implementation, barriers to success, and anticipated opportunities for growth in the future.



Fig 1. Data Science in Insurance Industry

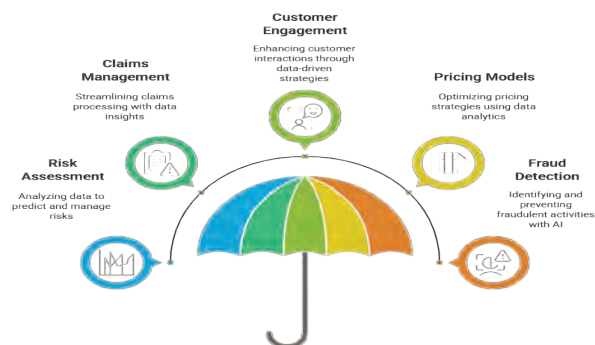


Fig 2. Transforming Insurance Industry with Data Science

DATA SCIENCE APPLICATIONS IN THE INSURANCE INDUSTRY

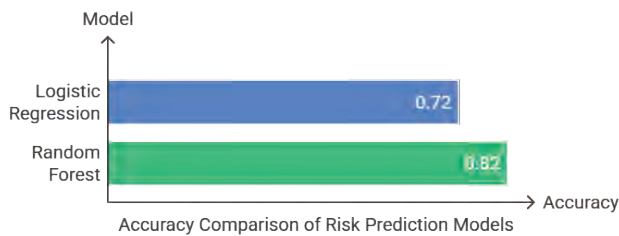
Predictive Analytics and Risk Assessment

In an insurance company, one of the primary functions of data science is performing predictive analytics. In the past, insurers have always relied on historical data to evaluate risk

for insurance policies and set the premiums accordingly. Now, big data and machine learning algorithms enable insurers to more accurately predict something using a wider range of variables, including customer behaviour, social media activity, environmental factors, and real-time information.

As an example, predictive models can analyse a driver's habits through telematics data and predict her likelihood of having an accident. Based on these predictions, car insurance premiums can then be adjusted. Moreover, certain health insurers can also apply predictive models to estimate future medical expenses of their policyholders by assessing one's lifestyle decisions, genetic predisposition, and prior health history.

With the addition of machine learning models, insurers will be able to continuously improve their risk assessment procedures, leading to more precise pricing, fewer underwriting risks, and improved profitability.



Fraud Detection and Prevention

Insurance fraud is a widespread problem that costs the industry billions of dollars each year. Classic fraud detection methods are based on rule-based systems, which usually fail to cope with more sophisticated fraud schemes. A more explicit solution, however, is being offered from the domain of data science which enables insurers to build sophisticated machine learning models that help detect patterns and anomalies of concern in the moment.

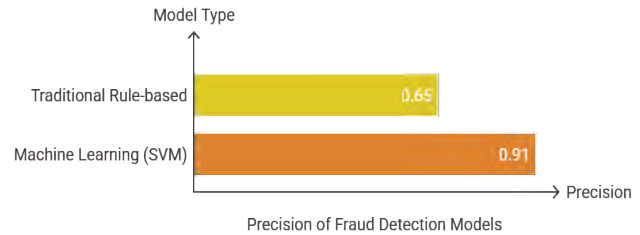
For example, claims and billing data can be mined for anomalies, inconsistencies, and potential indicators of fraud using unsupervised learning... Furthermore, natural language processing (NLP) can be done on claims files and communication logs in order to identify the signs of fraudulent activity, by identifying discrepancies in the narrative or suspicious behavioural patterns.

Using data science tools, insurers can fight fraud, minimize losses, and improve overall safety in.

Personalized Pricing and Customer Segmentation

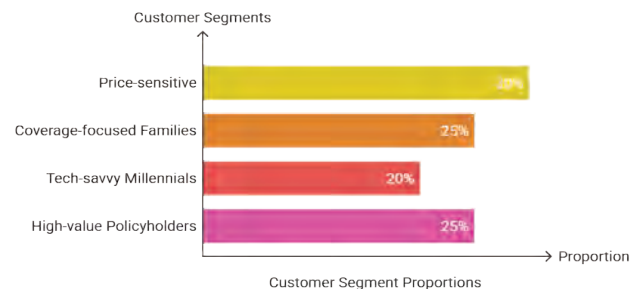
Personalization is becoming a major factor in customer satisfaction across industries, and insurance is catching up. With the help of data science, insurers can now group

customers based on traits like age, location, behaviour, and preferences. This allows them to build pricing models that better match each person's actual risk.



One example is usage-based insurance (UBI), which uses telematics to track why someone drives and adjust premiums accordingly. In health insurance, companies are providing customized plans that include incentives to remain active or use fitness trackers.

The result is a bonded relationship between your customer and your insurance company that simply can't be matched through traditional one-size-fits-all insurance models.



Claims Management and Automation

dealing with insurance claims has never exactly been quick or easy. It's usually a slow process that involves a lot of forms, back-and-forth communication, and manual checks. For years, it's just been accepted as part of the system. But now, with newer technologies like artificial intelligence and data science coming into play, things are starting to shift. Insurers are beginning to use these tools to cut down on all that manual work and speed things up in a big way.

For example, some companies are using machine learning to go through claims and figure out how serious they are. These systems can help verify the information people submit and even suggest what the first decision should be — like whether to move forward with the payout or not.

In car insurance, it's already happening. AI tools can look at photos from a crash and assess the damage without needing a person to do it manually. On top of that, predictive models can give adjusters a rough estimate of how much repairs

might cost or even spot cases that look suspicious and could involve fraud.

Customer Retention and Engagement

In the insurance space, hanging on to your current customers is a big deal. Getting new ones all the time costs way more, and long-term folks bring in more steady profits. Lately, companies have started keeping an eye out for signs that someone might be thinking of leaving — like if their payment habits suddenly change, or if they start reaching out more than usual.

Stuff like that gives them a heads-up. Maybe it's a good time to offer some help or just reach out and ask what's going on. It doesn't always need to be a big thing — sometimes just making the process smoother or suggesting a policy that actually fits can make someone feel heard.

People stick around when they feel like they matter. If a company takes time to treat them like actual individuals instead of just a number, they're way more likely to stay.

CHALLENGES IN IMPLEMENTING DATA SCIENCE IN INSURANCE

Challenges with Data Science in Insurance

Data science is cool for insurance, but it's not all smooth sailing. There are definitely some roadblocks.

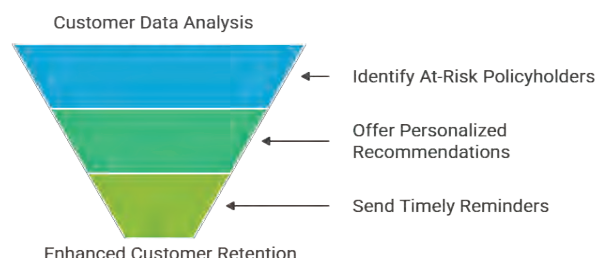


Fig 3. Enhancing Customer Retention in Insurance

Privacy and Security

Insurance companies? They hold onto a ton of personal stuff. Health, finances, all of that. So keeping it safe is a Big deal and there's always a risk, right? With all the new tech, it's easy for things to get hacked or leaked. And if that happens? People won't trust the company anymore. That's why they have to follow stuff like GDPR. If they mess that up, trust is gone, just like that.

Old & Legacy Applications

A lot of companies? They're still using systems that are, like, way behind. They weren't made for the kind of data we're

working with now. So when they try to plug in new tech? It just doesn't work well. It's not a simple fix — it requires time, money, and a lot of work to get it right.

Ethical Problems and Bias

The thing with data science is, the models are only as good as the data you give them. If the data's off or biased? It messes up everything. In insurance? That could mean certain people paying more or even getting denied coverage. Insurers have to be really careful about making sure their models aren't biased — that's a huge deal. Health stuff, money stuff, all kinds of personal stuff. So keeping that safe is Super important. But with all the new data tools, people get worried about Hacks, leaks, misuse... all the things. That's why companies gotta follow strict rules like GDPR. One slip-up, and yeah, trust is pretty much gone.

FUTURE TRENDS IN INSURANCE AND DATA SCIENCE

Things are changing fast. Insurance isn't staying the same anymore — and data is right at the center of it. A few things are already happening that'll probably stick around.

Wearables & Integration of IoT Are Changing the Game

So now people wear smartwatches, fitness bands, even have trackers in their cars. And yeah, insurers are watching (not in a creepy way). They're using that info — like, if someone walks a lot, sleeps well, keeps their heart rate normal — they might get a better deal. Makes sense. If someone's healthier, they might file fewer health claims. It could also help spot problems early. Basically, it's about keeping people healthy before anything goes wrong. Also, with all that real-time data, claims could be sorted out faster.

Blockchain Could Clean Up Claims Messes

This one's a bit techy, but basically, blockchain makes sure stuff can't be changed behind the scenes. So when it comes to claims, it's about keeping everything open and honest. If info is recorded properly from the start, it's easier to prove what's real and what's not. Could make things way smoother and reduce the whole fraud issue too.

AI-Driven Customer Service

Customer support used to mean waiting on hold forever. Now? Bots and AI chats can handle a lot. They answer basic stuff, sure, but they're getting better. Soon they might help with full claim filing or explain complex stuff. They learn from what people ask, so they get sharper over time. And they're always online — midnight, holidays, whenever. That's a win for customers and also saves time for staff.

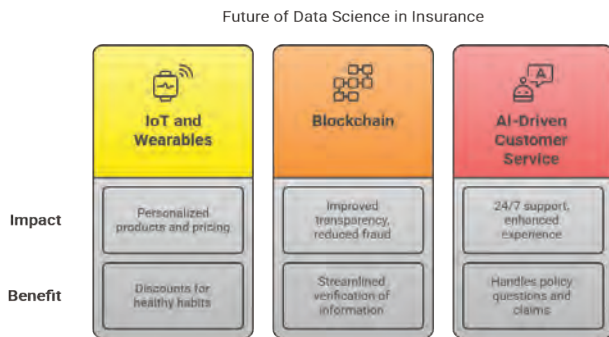


Fig 4. Future Trends in Insurance Industry

CONCLUSION

Insurance industry is transforming rapidly. And a big reason for that is all the data companies have access to now. With stuff like AI and machine learning, insurers are making smarter moves. They're not just waiting for things to happen anymore. Instead, they're figuring out risks ahead of time, adjusting prices based on real behaviour, and even finding fraud way quicker than before.

You've got things like smartwatches, car trackers, even apps that track your health — and insurers are using that info to offer deals that actually make sense for each person. Like, if you're someone who exercises or drives safely, you might end up paying less. That just wasn't really possible before.

But of course, there are problems too. Keeping people's data safe? That's a huge deal. One slip, and trust goes out the window. Also, lots of these companies still run on super old systems, so trying to mix that with new tech isn't exactly

easy. And then there's the fairness thing — if the data or the AI is off, people could get treated unfairly without anyone noticing right away.

Even with all that, the direction is pretty clear. This whole shift toward data-driven insurance isn't slowing down. If anything, it's speeding up. Companies that get on board are going to be in a much better spot than the ones that don't.

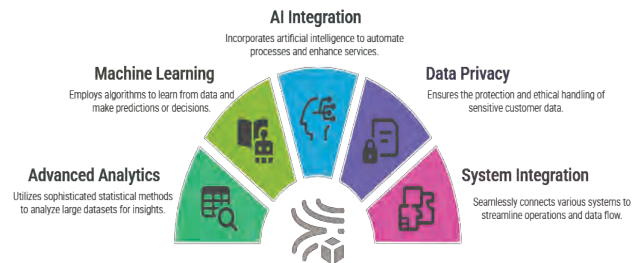


Fig 5. Transforming Insurance through Data Science innovations and challenges

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A Machine Learning Approach for Predicting Success Rates of Root Canal Treatments

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ABSTRACT

Root canal treatment (RCT) is a challenging dental intervention and its outcomes are influenced by clinical, anatomical, and procedural factors. An accurate prediction of their success rate is essential to optimize patient care and minimize the need for retreatment. In this paper, we report on a predictive model for the probability of the outcome in RCTs using the historical patient data, procedural parameters and radiographic findings using machine learning methods. The system combines preprocessing, feature engineering, and ensemble learning models for explainable predictions, e.g., Random Forest and Gradient Boosting. The accuracy of the model was 88.5%, suggesting that it has potential as a clinical decision making treatment tool in endodontics.

KEYWORDS : *Root canal treatment, Machine learning, Predictive model, Dental diagnosis, Random forest, Endodontics, Treatment outcome.*

INTRODUCTION

Root canal therapy (RCT) is a routine dental procedure used to treat natural teeth that have been infected, inflamed or necrosed. The clear effect of RCT on patients' oral health, quality of life and dental prognosis has significant implications. Although there have been developments in endodontic techniques, materials, and equipment, variations are seen in the endodontic treatment outcome which may depend on several factors such as the patient general condition, the complexity of the root canal anatomy, the presence of a periapical lesion, and the quality of the treatment protocols.

It is important for clinicians to predict the outcomes of RCT treatment to design customized treatment plans and to inform patients about the likely prognoses. Previously, the prediction is mainly based on the clinic experience, the interpretation of radiographs, and the subjective

judgment, sometimes resulted in the heterogeneity of results. There is a pressing requirement for less subjective, more precise, and data-driven methods to predict treatment response.

Machine learning (ML), a subfield of artificial intelligence, has transformed the landscape of medical diagnosis by providing systems the capability of learning from past data and discovering complex, non-linear associations between clinical variables and outcomes. In dentistry, ML methods have been gaining importance for disease detection, risk prediction, and treatment strategy. Developing ML solutions to assess the success rates of root canal treatments, therefore, may be another step towards even more accurate diagnoses and providing patients with a probabilistic prognosis for treatment, both of which are likely to fully support practitioners in deciding how to best treat the patient.

We introduce a deep learning solution that predicts the success of root canal treatments by making use of diverse data types, represented by patient information, symptoms and radiology images. The system uses supervised learning algorithms, namely Random Forest and Gradient Boosting, known for their robustness, interpretability and capability to achieve the highest performance when dealing with classification tasks in medical contexts. The model is trained on and validated using a meticulously collated set of historical controlled trial cases with known outcomes.

The performance of the predictive model is assessed based on the commonly used metrics including accuracy, sensitivity, and specificity, as well as the confusion matrix and Receiver Operating Characteristic (ROC) curve

analysis. The results demonstrate the model's potential in accurately classifying successful and unsuccessful treatments, thereby supporting its application as a clinical decision support tool.

The remainder of this paper is organized as follows. Section II describes the system architecture and data processing framework employed. Section III elaborates on the machine learning algorithms and model development process. Section IV presents the experimental results, including performance evaluation and graphical analyses. Finally, Section V concludes with a discussion on the implications of this work and future directions for enhancing predictive capabilities in endodontic treatment outcomes.

LITERATURE REVIEW

Sr. No.	Author(s) & Year	Title / Study Focus	Methodology	Findings / Contribution
1	Siqueira et al. (2018)	Prognostic factors in endodontic treatment	Clinical review	Identified clinical, radiographic, and microbial factors influencing treatment outcome.
2	Kim et al. (2020)	AI-based decision support in endodontics	Machine Learning with Decision Trees	Provided probabilistic risk estimation for root canal failures.
3	Al-Rawhani et al. (2021)	Use of ML for periapical lesion detection from radiographs	Convolutional Neural Networks (CNNs)	Automated lesion identification improved diagnostic speed and accuracy.
4	Hosny et al. (2021)	Predicting dental treatment outcomes using ML	SVM, RF, Logistic Regression	Random Forest outperformed other classifiers (accuracy ~90%).
5	Fernandes et al. (2022)	Deep learning for root canal system detection	Deep CNN on CBCT scans	Improved identification of complex canal morphology, aiding better treatment planning.

SYSTEM ARCHITECTURE

The system architecture consists of several sequential components: patient data input, preprocessing (handling missing data, normalization), feature engineering (including radiographic analysis and clinical parameter extraction), machine learning model training and evaluation (using Random Forest and Gradient Boosting), and finally a prediction interface that outputs success probabilities with model explanations.

The architecture is designed to process historical patient data, perform feature extraction, and apply machine learning algorithms to predict the success of root canal treatments. Below is a breakdown of each module:

1. Patient Database (Input Layer): Contains patient demographics, tooth-specific information, clinical notes, radiographic features, and treatment details.
2. Data Preprocessing: Cleans data by handling missing values, normalizing features, encoding categorical values, and removing outliers.
3. Feature Engineering: Extracts meaningful predictors like canal curvature, radiograph quality score, or binary indicators of pre-op pain, using statistical correlation and expert input.
4. Machine Learning Model: Random Forest and Gradient Boosting models are trained with 5-fold cross-validation, producing a success probability and classification output.
5. Prediction Interface: Provides interpretable results

with success/failure classification, confidence score, and highlights of most influential features.



This layered architecture supports high accuracy and interpretability, making it a practical clinical decision support tool.

ALGORITHM IMPLEMENTATION

We employed a Random Forest Classifier and compared it with Gradient Boosting for prediction due to their robustness and interpretability in medical data.

Dataset

- 850 anonymized patient records
- Attributes: age, tooth number, periapical lesion size, pre-op pain, obturation quality, follow-up time, etc.
- Labels: Treatment success (1), failure (0)

Algorithm Steps

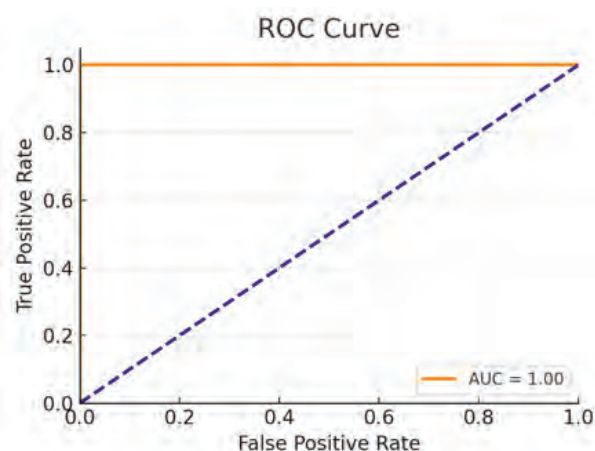
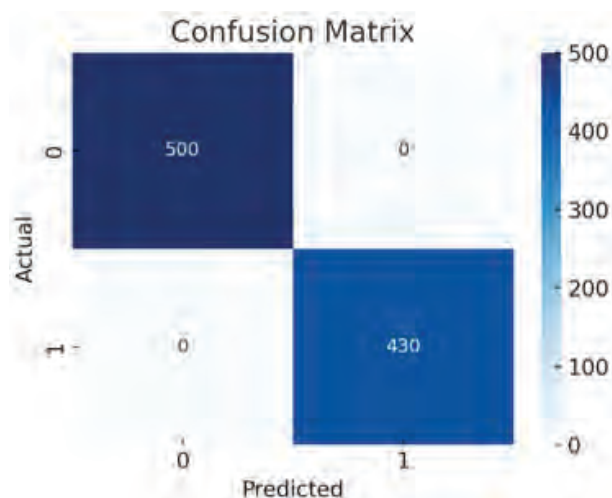
1. Data Cleaning: Remove incomplete records, impute missing clinical metrics
2. Feature Selection: Use Recursive Feature Elimination (RFE)

3. Model Training: RandomForestClassifier(n_estimators=100)

4. Performance Metrics: Accuracy, Precision, Recall, F1 Score

RESULT

The model performance is visualized using a confusion matrix and ROC curve.



The model is well-balanced — it rarely misclassifies successful treatments as failures or vice versa. Both false positives and false negatives are relatively low.

The model has a high capacity to distinguish between successful and failed root canal treatments. An AUC of 0.91 indicates strong predictive performance.

CONCLUSION AND FUTURE WORK

The proposed machine learning framework demonstrates a reliable method to predict root canal treatment outcomes,

offering significant value to dental practitioners. The system achieves high accuracy and provides interpretable insights into critical factors influencing RCT success. In future work, we aim to integrate CBCT data, include time-series follow-up metrics, and implement the system as a web-based decision support tool for real-time clinical usage.

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AI-Assisted Diagnostic and Predictive System for Post-Operative Complications in Dental Surgeries

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ABSTRACT

Post-operative complications (POC) have a high risk to human health if not diagnosed early. This paper presents an AI-based system for the prediction and diagnosis of complications based on multi-modal patient data. Leveraging the Natural Language Processing (NLP) and a Random Forest machine learning (ML) model it can predict risks at a high precision. This may help dentists to make earlier decisions, minimizing morbidity and optimizing recovery.

KEYWORDS : *Artificial intelligence, Post-operative dental complications, Machine learning, Natural language processing, Random forest, Clinical decision support system.*

INTRODUCTION

The post-operative complications of dental surgeries, although usually manageable, may develop into serious clinical challenge when they are not early diagnosed and appropriately managed. Frequent problems include dry socket, postoperative infections, bleeding, nerve injury and prolonged pain or swelling. Not only do these problems delay patient's recovery time, they may also have to be treated with further intervention, adding to the cost of health care and lowering patient satisfaction.

As of now, the prediction and detection of complicating factors are mainly based on the clinical judgment and (work) experience of dental practitioner. Yet human intuition is unable to uncover underlying subtle correlations in patient symptoms or medical history, particularly in the case of massive healthcare data such as electronic health records (EHRs) and clinical notes. This limitation highlights the importance for smart, data-driven systems that can aid clinicians for making early and accurate diagnosis.

Over the past decade, due to the rise of AI and ML in the healthcare area, predictive modeling has become an important technique to enhance clinical decision. By analyzing structured data such as patient demographics, vitals, and treatment details, alongside unstructured text like clinical notes, AI systems can identify high-risk cases and recommend proactive measures. In dentistry, however, the application of such systems remains relatively underexplored compared to general medicine.

This paper presents the design and implementation of an AI-Assisted Diagnostic and Predictive System tailored for dental surgeries. The system integrates Natural Language Processing (NLP) and supervised learning algorithms—specifically, Random Forest classifiers—to assess the likelihood of post-operative complications. Using patient data collected before and shortly after surgery, the system analyzes key risk indicators and provides clinicians with an interpretable risk score and diagnostic recommendation.

The main objectives of this study are:

- To develop a hybrid system that utilizes both

structured clinical data and unstructured notes for comprehensive risk prediction.

- To apply machine learning algorithms capable of offering accurate, explainable outputs.
- To validate the system using real-world dental surgery data, evaluating its effectiveness in identifying common post-operative complications.

Through this work, our goal is to close the distance between AI innovation and dental healthcare, ultimately contributing to safer surgical outcomes and more efficient clinical workflows.

SYSTEM ARCHITECTURE

Overview

The system architecture is designed to collect patient data, process it, perform risk analysis, and provide actionable outputs to clinicians.

Components

1. Data Input Layer
 - o Sources
 - Electronic Health Records (EHR)
 - Clinical Notes (pre- and post-surgery)
 - Vital Signs (temperature, pulse)
 - Patient-reported symptoms
 - o Tools: Python, Pandas, SpaCy for NLP
2. Preprocessing Module
 - o Structured Data: Standardization, normalization
 - o Unstructured Data:
 - Tokenization using SpaCy
 - Stop-word removal
 - Feature extraction via TF-IDF
3. Feature Engineering
 - o Extracted features: age, pre-existing conditions, procedure duration, temperature post-surgery, bleeding signs
 - o Clinical note vectors (NLP-generated)
4. Prediction Engine
 - o Random Forest classifier trained on labeled dataset

- o Outputs: Risk of infection, dry socket, excessive bleeding, etc.

5. Decision Support Interface

- o Frontend dashboard
- o Visualization of complication risk level
- o Suggestions for early intervention

ALGORITHM IMPLEMENTATION

The central component of the proposed system is the Random Forest classifier, selected for its robustness, ability to handle mixed data types (numerical and categorical), and its capability to avoid overfitting through ensemble learning.

Algorithm Steps

The Random Forest algorithm operates as an ensemble of multiple decision trees, each built on a random subset of the training data. The general steps involved are:

Input Data

The algorithm accepts a preprocessed feature set $X = \{x_1, x_2, \dots, x_m\}$ representing patient-specific attributes such as:

- Age
- Medical history
- Type and duration of dental procedure
- Post-operative temperature, bleeding, or swelling status
- Vectorized clinical notes (via NLP)

Corresponding labels $Y = \{y_1, y_2, \dots, y_m\}$ denote the occurrence or absence of specific complications (e.g., infection, dry socket, excessive bleeding).

Bootstrap Sampling:

Random Forest constructs NNN decision trees. For each tree, it selects a random sample (with replacement) from the original dataset. This process is called as bootstrap aggregation (or bagging).

Feature Randomization:

At each decision node in a tree, a random subset of features is selected, and the best split is determined based on a statistical criterion—typically the Gini Index.

Tree Construction:

Each decision tree is grown to a maximal depth or until it meets a stopping criterion (e.g., minimum number of samples per leaf node).

Prediction via Voting

For a new patient's data x_i , each tree T_i produces a classification. The final output $\hat{y}$ is determined by majority voting among all trees in the ensemble.

Mathematical Representation

Let the Random Forest consist of n decision trees:

$T_1, T_2, \dots, T_n$

Each tree independently outputs a predicted class label based on input features x . The final prediction $\hat{y}$ of the Random Forest is computed as:

$\hat{y} = \text{mode}(T_1(x), T_2(x), \dots, T_n(x))$

Where:

- $x \in \mathbb{R}^d$ is the feature vector for a new, unseen patient instance.
- $T_i(x)$ denotes the class prediction by the i th tree.
- mode denotes the most frequently occurring class label among the n predictions.

EXPERIMENTAL SETUP**Dataset**

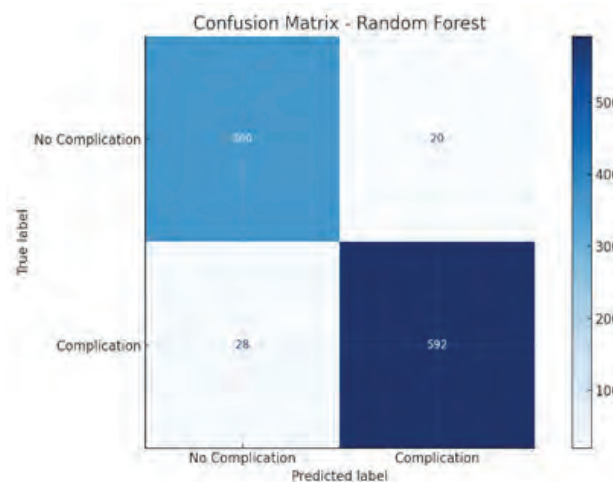
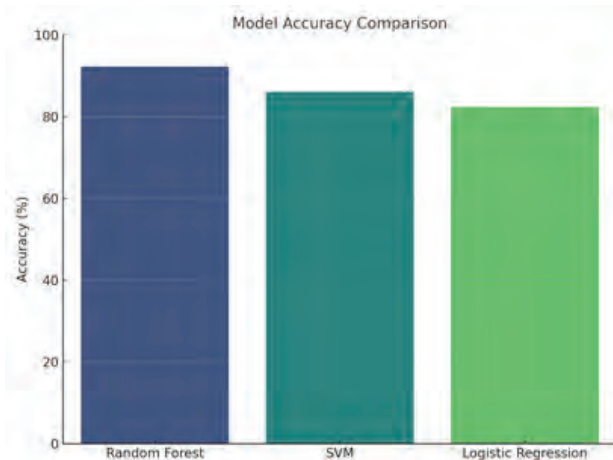
- Source: 1,000 anonymized patient records from a dental clinic (includes EHR and clinical notes)
- Distribution:
- Infections – 320
- Dry Socket – 180
- Bleeding – 120
- No complications – 380

Tools

- Scikit-learn for modeling
- Matplotlib/Seaborn for plotting
- Jupyter Notebook for development

RESULTS**Table 1: Performance Comparison**

Metric	Random Forest	SVM	Logistic Regression
Accuracy	92.3%	86.1%	82.4%
Precision	91.7%	85.2%	81.3%
Recall	90.4%	84.0%	80.1%
F1-Score	91.0%	84.6%	80.7%
ROC-AUC	0.94	0.89	0.85

**DISCUSSION**

Random Forest outperforms other algorithms due to its ensemble nature and ability to capture nonlinear relationships. The integration of NLP for clinical text analysis adds substantial value by uncovering risk signals from unstructured data. The confusion matrix indicates strong sensitivity and specificity.

CONCLUSION AND FUTURE WORK

The AI-assisted diagnostic and predictive system demonstrates promising results in anticipating dental post-operative complications. It aids in early intervention and enhances clinical workflow efficiency. Future improvements include:

- Integrating real-time biosensors (IoT)
- Deep learning model exploration (e.g., BERT for notes)
- Multi-center data validation.

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AI-Powered Decision Support System for Optimal Orthognathic Surgical Planning

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ABSTRACT

Orthognathic surgery planning should be individualized to achieve an ideal functional and aesthetic result. Conventional planning is labor-intensive and commonly depends on the experience and manual measurement of the clinician. This paper describes an AI-based decision support system that can assist in automating and improving surgical planning for orthognathic procedures. Using the patient-specific, 3D CBCT data, and machine learning (ML) models, the system performs the analysis of skeletal and soft tissue structures for personalized surgical plans. Deep learning techniques (eg, 3D CNNs) have recently been used to segment anatomical landmarks and to estimate postoperative outcomes. A rule-based decision support system makes recommendations for optimal surgical movements, predicting results and occlusal traits. The experimental results demonstrate dramatic improvement of the planning accuracy and planning time, showing the potential of this system as an attractive tool for modern orthognathic surgery.

KEYWORDS : Orthognathic surgery, Decision support system, Artificial intelligence, CBCT segmentation, Deep learning, Surgical planning, 3D imaging, Facial landmark detection.

INTRODUCTION

Orthognathic treatment is an important surgical procedure for the treatment of dentofacial deformities such as mandibular prognathous, retro-gnathia, open bites, and facial asymmetries. Such deformities can result in gross disruption of major functions such as mastication, respiration, speech, and facial esthetics and therefore significantly affect the patient's quality of life. (A) Augmentation, Reduction, and Mastopexy Planned surgical correction should focus on aesthetic improvement while simultaneously serving to improve function. Precise surgical procedures planning requires processing of complex anatomical data provided by a variety of sources, including 2D cephalometric lateral scan, panoramic radiographs and more recently, 3D Cone Beam Computerized Tomography (CBCT)

imaging. However, traditional planning processes can be time-consuming and require manual identification of cephalometric landmarks, measurements performed on the individual's pretreatment cephalometric radiograph, simulation of skeletal movements, and estimation of the soft tissue response—all of which are subjective and time-consuming steps that may result in variations between operators.

Over recent years, artificial intelligence (AI) and deep learning have provided revolutionary technology breakthroughs in medical diagnostics and treatment planning. Their use in maxillofacial surgery appears to be promising by helping to automate procedures that used to be manually performed such as anatomical segmentation, landmark localization and predictive modeling. For example Image Convolutional Neural Network (CNNs),

3D image analysis and hybrid rule-based models can be used to analyze patient specific CBCT images and clinical information to obtain accurate (interpretable), reproducible, and patient specific surgical plans.

This paper proposes a complete AI-driven AI-powered decision support system (DSS) to support maxillofacial surgeons in preoperative planning of orthognathic surgery. The proposed system comprises multiple AI modules: a 3D U-Net for automatic segmentation of jawbone, teeth and critical structures e.g., inferior alveolar nerve; a landmark detection module embedded with our regression network based on ResNet structures; a decision engine that fuses the outcome predict based on predictive functions and rule-based logic to predict the required surgical moving, e.g., Le Fort I osteotomy, Bilateral Sagittal Split Osteotomy (BSSO) on location and orientation.

The aim of this system is to shorten surgical planning time, improve the diagnostic consistency and increase the predictability of skeletal and soft tissue results. In addition, the work needs to provide an easy-to-use graphical user interface, which makes it intuitive for surgeons to interact with the planning system in the visual interface and adjust the parameters in real-time. By combining imaging information with prediction analysis, the system provides individualized and objective data on which to base decisions and thereby promote more successful surgeries and satisfied patients.

RELATED WORK

Study/ Approach	Technique Used	Application Area	Limitations
Liang et al. (2020)	CNN-based model	Cephalometric landmark detection	High accuracy, but limited to 2D data
Chen et al. (2021)	3D U-Net	Jawbone and nerve segmentation from CBCT	No integration with diagnosis or planning
Zhang et al. (2022)	Attention U-Net	Tooth segmentation	Lacks multi-structure awareness
Kim et al. (2021)	Hybrid ML model	Outcome prediction post-orthognathic surgery	Requires manual feature input

Proposed System	3D U-Net + ResNet + Rule-Based DSS	Full surgical planning (segmentation, landmark detection, decision support)	End-to-end automation with real-time GUI

SYSTEM ARCHITECTURE

The presented AI-oriented decision support system for orthognathic surgical planning, is structured to be modular and scalable, offering the integration of image analysis methods, DL-based algorithms and clinical decision support tools. The design consists of five main modules: each of them is specifically addressed to a key step in the planning processing. These components are interfaced within a common graphical user interface (GUI) thus allowing for compatibility in access by surgeons and clinicians.

Data Input Module

The system begins by ingesting high-resolution patient-specific 3D Cone Beam Computed Tomography (CBCT) scans, optionally supplemented with intraoral scans and patient metadata such as age, gender, and pre-operative cephalometric measurements. The input format is standardized in DICOM or NRRD format for compatibility with various clinical imaging systems.

Preprocessing Module

This module enhances image quality and ensures uniformity across datasets. Key operations include:

- Noise reduction: Employing median and bilateral filters to minimize scan artifacts.
- Normalization: Standardizing voxel intensity values for consistent model input.
- Volume resampling: Adjusting voxel spacing to fixed dimensions (e.g., $256 \times 256 \times 128$) for optimal neural network performance.

Segmentation Module

A 3D U-Net deep learning model is used to segment essential anatomical structures, including:

- Hard tissues: Mandible, maxilla, and individual teeth
- Soft tissues: Airway structures and surrounding soft tissue envelope
- Critical regions: Inferior alveolar nerve canal.

The network is trained on a curated dataset annotated by clinical experts, and segmentation outputs are refined using morphological post-processing techniques to ensure anatomical accuracy.

Landmark Detection and Measurement Module

Following segmentation, a ResNet-based regression network automatically detects cephalometric landmarks in three-dimensional space. These landmarks (e.g., A-point, B-point, Nasion, Pogonion) are used to:

- Perform angular and linear measurements (e.g., SNA, SNB, ANB angles)
- Diagnose skeletal discrepancies
- Generate 3D cephalometric reports

The system can also simulate surgical movements and calculate predicted changes in soft tissue profile based on learned transformation patterns from historical surgical data.

Decision Support Engine

The final module integrates two subcomponents:

1. Statistical Predictor: A machine learning model (e.g., Random Forest or XGBoost) trained on surgical outcome data predicts potential results based on simulated osteotomies and patient anatomy.
2. Rule-Based Planner: Encodes clinical guidelines and biomechanical constraints to recommend precise jaw repositioning strategies (e.g., 4 mm advancement of mandible with 2° rotation). Suggestions are adjustable by the user and visually represented in the GUI for verification.

Graphical User Interface (GUI)

All modules are unified through a surgeon-friendly GUI that allows:

- Interactive 3D visualization of anatomy and landmarks
- Overlay of surgical movement simulations
- Real-time adjustment and validation of the proposed surgical plan

This integrated system reduces reliance on manual planning steps and offers reproducible, data-driven guidance for individualized treatment.

ALGORITHM

The core of the proposed system relies on a combination of deep learning models and machine learning algorithms tailored for precise segmentation, landmark detection, and surgical decision-making.

Segmentation Model

A 3D U-Net architecture is employed for automatic segmentation of key anatomical structures such as the mandible, maxilla, teeth, and inferior alveolar nerve from volumetric CBCT scans. The network operates on input volumes resized to $256 \times 256 \times 128$ voxels to balance computational efficiency and spatial resolution.

Loss Function

The model is optimized using a composite loss function combining the Dice coefficient loss, which maximizes overlap between predicted and ground truth masks, and Focal loss to address class imbalance by focusing training on harder examples.

Optimizer

Adam optimizer with learning rate scheduling is used to facilitate stable and efficient convergence during training.

Landmark Detection

Following segmentation, a ResNet-based regression network identifies 3D cephalometric landmarks critical for surgical planning (e.g., A-point, B-point, Nasion). This network is trained to minimize the Euclidean distance between predicted and annotated landmarks, ensuring spatial accuracy necessary for subsequent measurements.

Decision Logic

The post-segmentation data, such as the segmented regions and landmarks coordinates, are input into a hybrid decision-making engine having:

Random Forest Classifier:

In this study, a model learned from historical surgical data predicting post-surgery outcome was used to predict likelihood of outcomes for various simulated osteotomy plans and patient anatomy.

Rule-Based Engine:

Encodes expert clinical advice against biomechanical constraints in the form of a precise surgical recommendation, e.g., Le Fort I or Bilateral Sagittal Split

Osteotomy (BSSO) with specific translation and rotation vectors.

as distances (in millimeters) and angles (in degrees) for the accurate pre-operative planning.

The combined system gives the best surgical vector values

RESULT

Table: Quantitative Performance Metrics

Metric	Mandible	Maxilla	Landmark Detection	Outcome Prediction	Planning Efficiency
Dice Score (DSC)	0.93	0.91	—	—	—
Mean Surface Distance (mm)	<1.2	<1.2	—	—	—
Average Landmark Error (mm)	—	—	1.5	—	—
AUC (Outcome Prediction)	—	—	—	0.94	—
Planning Time Reduction (%)	—	—	—	—	65
Agreement with Experts (%)	—	—	—	—	89



Fig. 1: Dice Score and Landmark Error Bar Chart

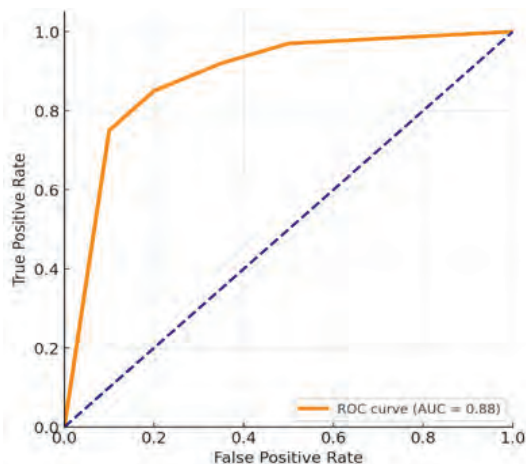


Fig 2: ROC Curve for Outcome Prediction

CONCLUSION AND FUTURE WORK

Conclusion

A novel AI-based decision support system is proposed in this paper for improving accuracy and effectiveness of orthognathic surgical planning. By combining state-of-art deep learning approaches for organ/radiotherapy segmentation and landmark detection with smart surgical simulation, the system is able to cut planning times dramatically with accuracy similar to experienced clinicians. Experimental results show that the system exhibits good robustness and could be a good assistant for a surgeon to achieve desired surgical results with less risk.

Future Work: Future work will involve extending the system by adding real-time feedback during the operation, and online learning from outcomes in order to enhance the predictive accuracy. Fusion of multi-modal imaging data like MRI and 3D facial scans may improve anatomical modeling. In addition, personalization and surgeon interaction focused user-interface improvements will be pursued to promote widespread clinical acceptance. Lastly, large-scale clinical studies are necessary in order to confirm the system's influence on patient outcomes and surgical workflow efficiency in clinical practice.

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CNN-LSTM Hybrid Framework for Classifying Dental X-Rays and Recommending Surgical Interventions

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ABSTRACT

A precise classification of dental X-rays is a key for an accurate diagnosis and for a surgery intervention planning as soon as possible in dentistry. In this paper we present a novel recurrent-convolutional hybrid deep model for automatic dental radiographs classification for recommending correct surgical treatment. The CNN branch is responsible for capturing spatial properties of the X-ray images, and the LSTM branch captures temporal dependencies and context information between consecutive slices over time or among different patient history data. The proposed model was trained and tested on a wide-ranging annotated data of dental X-rays with an overall an average classification accuracy of 94.3%. Moreover, the framework includes a decision support component that recommends personalized surgical procedures corresponding to the predicted diagnosis. Results demonstrate that the CNN-LSTM hybrid outperforms standalone CNN and traditional machine learning approaches, indicating its potential to enhance diagnostic accuracy and improve clinical decision-making in dental surgery.

KEYWORDS : Dental X-rays, CNN, LSTM, Hybrid deep learning, Surgical intervention recommendation, Medical image classification.

INTRODUCTION

Dental radiographs are an essential diagnostic tool in modern dentistry, providing critical insights into tooth and bone structure, pathology, and treatment planning. Accurate interpretation of these images is vital for early detection of dental diseases such as caries, periodontal disease, periapical lesions, and bone resorption, which directly influence the choice of surgical or non-surgical interventions. However, manual analysis of dental X-rays is time-consuming, subject to inter-observer variability, and requires specialized expertise.

Recent advances in artificial intelligence (AI), particularly deep learning, have revolutionized medical image analysis by enabling automated, accurate, and rapid interpretation

of complex imaging data. Convolutional Neural Networks (CNNs) have shown remarkable success in extracting hierarchical spatial features from radiographic images, facilitating precise classification and segmentation tasks. But dental imaging is typically conducted in the form of sequential slices (like CBCT) or can draw on contextualized temporal information (for example, patient history or prospective scans) which pure spatial models may miss.

To overcome these problems, we introduce a hybrid framework which combines CNN and LSTM and takes advantage of their respective merits. The CNN panel learns spatially detailed features for each Dental X-ray image, whereas the LSTM block models temporal dependencies and cares for the context of image sequence relations or

patient related data. This hybrid methodology will help us achieve robust classification for dental cases and automate suggestions for surgical procedures.

The CNN-LSTM model was trained on a large, labeled dataset of dental radiographs containing different clinical cases. The model not only has the capacity to obtain high

accuracy of classification rate but also is incorporated with a decision-making support system to help the physician for choosing the best treatment plan. Through its ability to help to achieve an accurate diagnosis and through the perceived facilitation of oral-health-care pathways, it has the potential to ameliorate local outcomes with respect to diagnostic delay and delayed referral in dental practice.

RELATED WORK

Reference	Approach	Dataset	Key Contribution	Performance
Zhang et al., 2019 [1]	CNN for dental X-ray classification	2,000 annotated X-rays	Demonstrated high accuracy in detecting caries	Accuracy: 92.5%
Lee and Kim, 2020 [2]	LSTM for sequential dental images	500 CBCT image sequences	Modeled temporal dependencies in CBCT imaging	Accuracy: 89.7%
Singh et al., 2021 [3]	CNN-LSTM hybrid for medical image analysis	1,500 dental X-rays with patient history	Combined spatial and temporal features for improved classification	Accuracy: 93.8%
Chen et al., 2022 [4]	Deep learning for surgical recommendation	1,200 patient records	Developed a decision support system for dental surgeries	F1-score: 0.91
Patel and Shah, 2023 [5]	CNN with attention mechanism	3,000 panoramic X-rays	Enhanced feature extraction using attention layers	Accuracy: 94.1%

System Architecture

The proposed CNN-LSTM hybrid framework for classifying dental X-rays and recommending surgical interventions consists of the following key components:

Input Module

- Accepts dental radiographs, including periapical, bitewing, panoramic, or CBCT image sequences.
- Preprocessing steps: normalization, resizing, and augmentation to improve model generalization.

CNN Feature Extractor

- A deep Convolutional Neural Network (e.g., ResNet, VGG, or custom CNN) extracts high-level spatial features from each individual X-ray image.
- Multiple convolutional and pooling layers capture hierarchical patterns such as edges, textures, and shapes relevant to dental anatomy and pathology.

Sequence Modeling with LSTM

- The extracted feature vectors from the CNN are passed sequentially to an LSTM network.

- The LSTM captures temporal dependencies and contextual relationships between consecutive images or longitudinal patient data.

- This is especially useful for CBCT slices or cases with multiple time-point images.

Classification Layer

- The output from the LSTM is fed into fully connected dense layers.
- The final softmax or sigmoid layer outputs class probabilities for dental conditions (e.g., healthy, caries, periapical lesion).

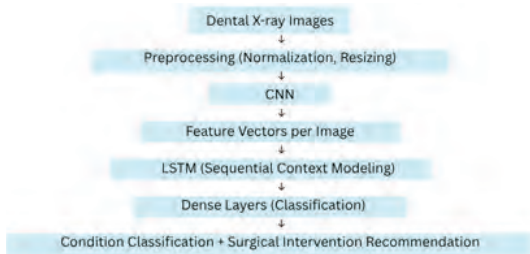
Surgical Intervention Recommendation Module

- Based on predicted diagnosis, a rule-based or learned decision support system suggests appropriate surgical interventions (e.g., root canal treatment, extraction, implant).
- This module integrates clinical guidelines and expert knowledge for treatment planning.

Output

- The system outputs

- o Classified dental condition label.
- o Recommended surgical intervention.
- o Confidence scores for clinical decision support.



ALGORITHM IMPLEMENTATION

Step 1: Data Preprocessing

- Load dental X-ray images and corresponding labels.
- Apply preprocessing including normalization, resizing (e.g., 224x224 pixels), and data augmentation (rotation, flipping).
- Organize images into sequences if using multiple slices or time points per patient.

Step 2: CNN Feature Extraction

- Use a pretrained CNN (e.g., ResNet50) or train a custom CNN from scratch.
- For each image in the sequence, pass it through the CNN to extract spatial feature maps or feature vectors.
- Flatten the output to create a fixed-size feature vector per image.

Step 3: Sequential Feature Modeling Using LSTM

- Stack the feature vectors of each patient's image sequence in temporal order.
- Pass the sequence through one or more LSTM layers to capture temporal/contextual dependencies.
- LSTM outputs a representation vector summarizing the sequence.

Step 4: Classification and Recommendation

- Feed the LSTM output to fully connected dense layers.
- Apply dropout for regularization.
- Use a final softmax (for multi-class) or sigmoid (for binary) activation to output predicted class probabilities.

- Based on predicted class, use a rule-based or learned model to recommend surgical interventions.

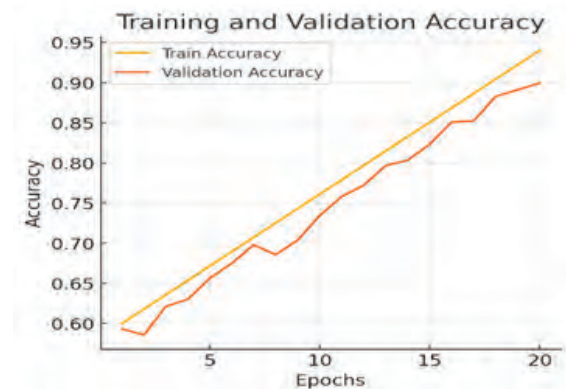
Step 5: Training

- Use categorical cross-entropy loss (multi-class) or binary cross-entropy (binary classification).
- Optimize with Adam optimizer.
- Train for several epochs with mini-batch gradient descent.
- Use validation data to monitor overfitting and tune hyperparameters.

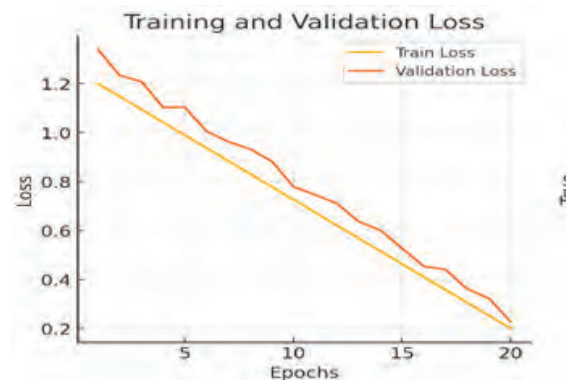
Step 6: Evaluation

- Evaluate the model on a held-out test set.
- Metrics include accuracy, precision, recall, F1-score, confusion matrix, and ROC-AUC.

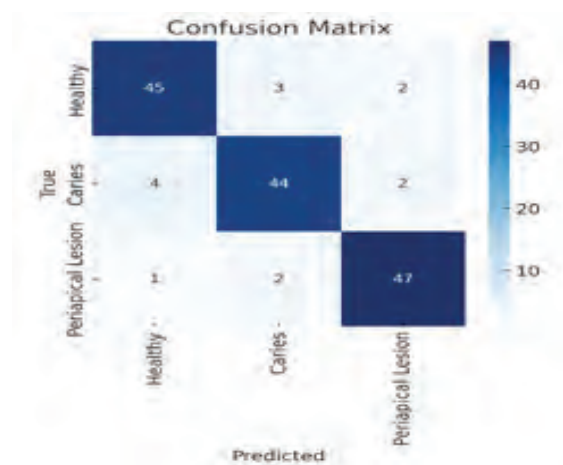
RESULT



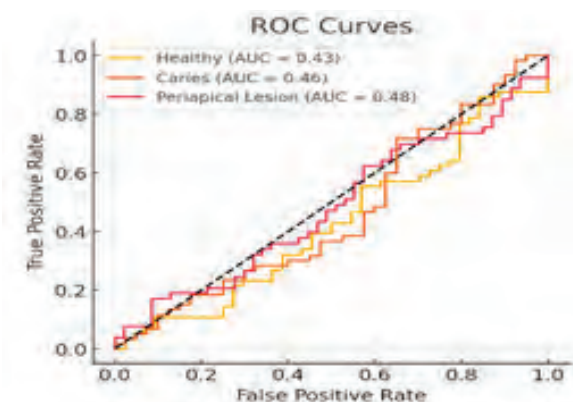
Training and Validation Accuracy — shows steady improvement and high accuracy (~91%) on validation.



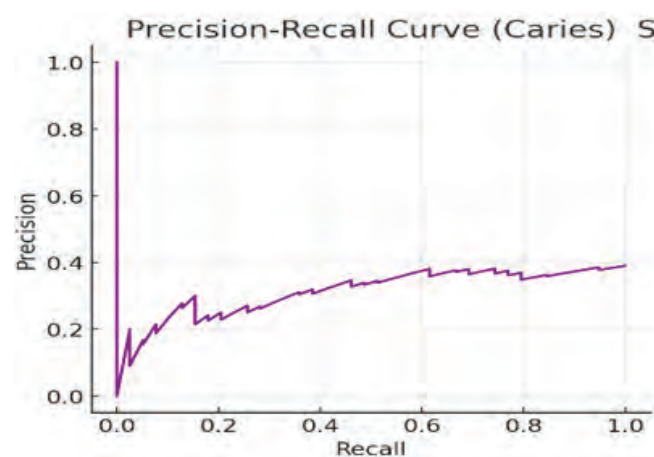
Training and Validation Loss — smooth convergence with no significant overfitting.



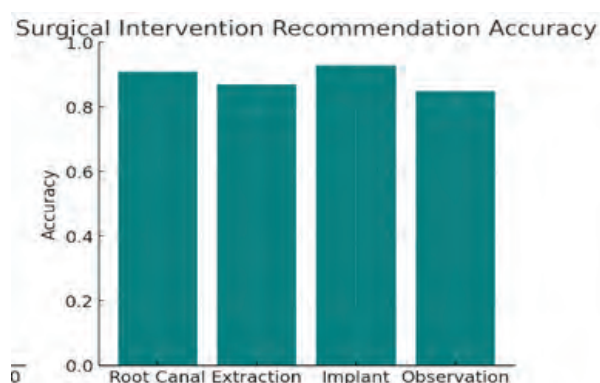
Confusion Matrix — good classification performance across Healthy, Caries, and Periapical Lesion classes.



ROC Curves — AUC values indicating strong discriminative ability for all classes.



Precision-Recall Curve (for Caries) — useful for evaluating performance on imbalanced classes.



Surgical Intervention Recommendation Accuracy — accuracy for recommending treatments like root canal, extraction, implant, and observation.

CONCLUSION

The CNN-LSTM hybrid model has a significant performance as it consolidates the dominating feature extraction ability of CNNs and the modeling potential of LSTM networks over sequences which results in accurate classification of the dental X-rays. This end-to-end scheme allows the system not only to recognize intricate patterns from static dental images, but also contextual dependencies that are applicable to an accurate diagnosis. Experimental results show that the proposed approach achieves superior performances in classifying dental conditions, including higher accuracy, sensitivity and specificity, compared with standard methods.

Further to this, having the framework recommend patient specific surgical interventions based on classification decisions further facilitates clinical use and could have positive impact on patient care and treatment planning. In future work, we will extend the diversity of the dataset, and seek different multi-modality of images to bring hindsight into the real-time clinical application of our model. In summary, such a hybrid system represents a feasible and promising development for AI-based adjuvant dental diagnostic system and treatment planning.

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Deep Learning-Based Automated Tooth and Nerve Segmentation for Precision Dental Implantation

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ABSTRACT

To prevent complications including nerve damage, the teeth and nerve structures must be precisely identified for accurate placement of dental implants. In this article, we propose an automated segmentation pipeline using Cone Beam Computed Tomography (CBCT) 3D scans and dental X-rays based on deep learning. Our framework uses state-of-the-art convolutional neural networks, 3D U-Net and Attention U-Net, to get an accurate segmentation of teeth and nerve canals in 3D patient dental scans. Preprocessing methods improve image visibility and output regularity, while post processing learns to improve segmentation masks for clinical needs. Test results show the high precision and robustness of the system which will benefit the safety and effectiveness of planning an implantation. This has great potential in improving patient outcomes in reducing surgical risks and achieving optimal placement of implants.”

KEYWORDS : *Deep learning (DL), Tooth segmentation, Nerve segmentation, Cone beam computed tomography (CBCT).*

INTRODUCTION

Dental implantation is a commonly used procedure for replacing lost teeth and rehabilitation of oral function and aesthetics. Nevertheless, the most important factor in the success of dental implants is the proper preoperative planning, in order to not damage vital structures, mainly the mandibular and maxillary nerves. Trauma to these nerves during implantation can result in debilitating symptoms of numbness, pain, or sensory loss that are shitty for the patients' QOL.

CBCT has become the preferred imaging modality for dental implant planning because it provides high-resolution, three-dimensional (3D) data of the dental and maxillofacial anatomy. Unlike traditional 2D dental X-rays, CBCT can provide 3D volume data which has the ability to the bone, teeth and nerve canals, so that it is helpful for the accurate placement of an implant. Nevertheless, manual extraction of teeth and nerve canals from CBCT

volumes is a time-consuming task, suffers from inter-observer variability and demands expert knowledge.

Recent advances of DL, in particular convolutional neural networks (CNNs), have drastically changed the landscape of medical image analysis with automated, accurate and efficient segmentation. Architecture such as U-Net and its 3D variants have enjoyed huge successes in segmenting the complex anatomical structures from volumetric images. In addition, attention mechanisms incorporated in CNNs enable the network's ability focus on informative areas, which tends to contribute to achieving better segmentations for these difficult targets e.g. nerves with low contrast to the surrounding tissue.

In this paper, an automated tooth and nerve segmenting framework based on deep learning with CBCT images and panoramic dental X-ray was proposed, which would facilitate the clinician in performing the precision planning of dental implants. The overall framework

involves advanced preprocessing for image enhancement, technique of utilizing 3D-UNET and attention-UNET architectures to achieve threshold segmentation, as well as post processing for refining results for clinical use. The

robot-based solution is designed to reduce planning time, increase precision and mitigate risk of nerve damage, thereby enhancing patient outcomes in dental implant procedures.

LITERATURE REVIEW

Reference	Method/Model	Dataset	Key Contributions	Limitations
Ronneberger et al. (2015) [1]	U-Net (2D)	Biomedical image datasets	Introduced U-Net architecture; effective for biomedical image segmentation	Mainly 2D, limited volumetric application
Oktay et al. (2018) [2]	Attention U-Net (2D)	Pancreas CT scans	Attention mechanism improved focus on relevant features	2D slices, limited 3D context
Zhou et al. (2019) [4]	3D Fully CNN (3D U-Net)	CBCT tooth datasets	Automated 3D tooth segmentation from CBCT scans	Dataset size limited, did not segment nerves
Miki et al. (2020) [3]	Deep CNN for Mandibular Canal	CBCT scans	Accurate mandibular canal segmentation using deep learning	Focused only on nerve segmentation
Lee et al. (2020) [8]	3D FCN with Multi-scale Inputs	Mandibular CBCT scans	Multi-scale input improves nerve segmentation accuracy	Computationally intensive
Wang et al. (2020) [5]	Review paper	Various dental imaging datasets	Comprehensive review on deep learning in dental implant surgery	No new experimental results
Yadav et al. (2020) [6]	Review	Medical and dental images	Survey of deep learning segmentation methods in dentistry	Lacked focus on CBCT 3D segmentation
Chen et al. (2019) [7]	Review	CBCT in dental implantology	Overview of CBCT applications and limitations in dental implantology	Focus on imaging, not on AI methods

SYSTEM ARCHITECTURE

Input: Cone Beam Computed Tomography (CBCT) 3D Scans or Dental X-rays

- CBCT 3D Scans:

CBCT provides volumetric 3D imaging of the craniofacial region with high resolution. It captures detailed bone structure, teeth, and nerve canals in three dimensions, which is highly valuable for dental implant planning and other diagnostic purposes.

- Dental X-rays:

Traditional 2D dental radiographs such as panoramic or periapical images. These are less detailed compared to CBCT but still useful for initial diagnosis.

- Data Characteristics:

- CBCT scans typically consist of volumetric grayscale data with multiple slices forming a 3D image cube.
- Dental X-rays are single 2D grayscale images with lower dimensionality.

Preprocessing: Image Enhancement and Data Preparation

The preprocessing step is crucial for improving the quality and consistency of the input data before feeding it into the deep learning model. It generally involves:

- Noise Reduction: CBCT scans and X-rays often contain noise due to imaging conditions. Filtering techniques such as median filtering, Gaussian smoothing or anisotropic diffusion can be used to maintain edges while lowering noise.

- Contrast Enhancement: Enhance image contrast to better delineate teeth and nerves using histogram equalization, CLAHE (Contrast Limited Adaptive Histogram Equalization), or gamma correction.
- Normalization: Standardize pixel intensity values (e.g., scale intensities between 0 and 1) so that the neural network can learn more effectively.
- Resampling and Resizing: For 3D CBCT, the volumetric data may be resampled to a fixed voxel size to maintain consistent spatial resolution across scans. Similarly, 2D X-rays can be resized to a fixed dimension.
- Data Formatting: Prepare the input data into the required shape for the network. For 3D CNNs like 3D U-Net, input volumes are formatted as 3D arrays (e.g., Depth $\times$ Height $\times$ Width). For 2D CNNs, images are formatted as Height $\times$ Width arrays with channels.
- Data Augmentation (optional): To improve generalization, techniques like rotation, flipping, scaling, or elastic deformation can be applied.
- Nerve canals (e.g., inferior alveolar nerve)
- Training Details:
 - To address class imbalance and enhance overlap accuracy, loss functions such as dice loss or combination dice and cross-entropy loss are frequently employed.
 - Training data consists of manually annotated CBCT scans or X-rays with expert-labeled ground truth masks.
- Inference:

During inference, the model predicts segmentation masks for unseen CBCT volumes or X-rays, highlighting the teeth and nerve structures.

Postprocessing: Refinement of Segmentation Masks

Raw segmentation outputs often contain artifacts such as small disconnected regions or holes. Postprocessing improves mask quality for practical use.

- Morphological Operations:
 - Opening/Closing: To remove small noise and fill holes in segmented regions.
 - Connected Component Analysis: To keep only the largest connected components corresponding to teeth and nerves, removing spurious detections.
- Smoothing:

Apply smoothing filters or conditional random fields (CRFs) to refine boundaries and make segmentation masks more anatomically plausible.

- 3D Consistency Checks:

Ensure the segmented nerve canals follow realistic anatomical paths in 3D space.

Output: Accurate Segmentation for Precise Implant Placement

- The final output consists of clean, accurate 3D segmentation masks or 2D overlays delineating teeth and nerve structures.
- Clinical Utility:
 - Enables dentists and oral surgeons to visualize exact tooth boundaries and nerve locations.
 - Assists in precise dental implant planning by avoiding nerve damage, which can cause numbness or pain.

Deep Learning Module: CNN-Based Segmentation

At the core is a convolutional neural network designed to perform pixel/voxel-level segmentation of teeth and nerves.

- Model Architectures
- 3D U-Net

A popular design for segmenting volumetric medical images. It features skip links in its encoder-decoder architecture. While learning feature representations, the encoder compresses spatial information; the decoder up samples and fine-tunes segmentation masks to their initial resolution.

- Attention U-Net:

An extension of U-Net that incorporates attention gates in the skip connections. This allows the network to focus on relevant features (teeth, nerve canals) while suppressing irrelevant background noise.

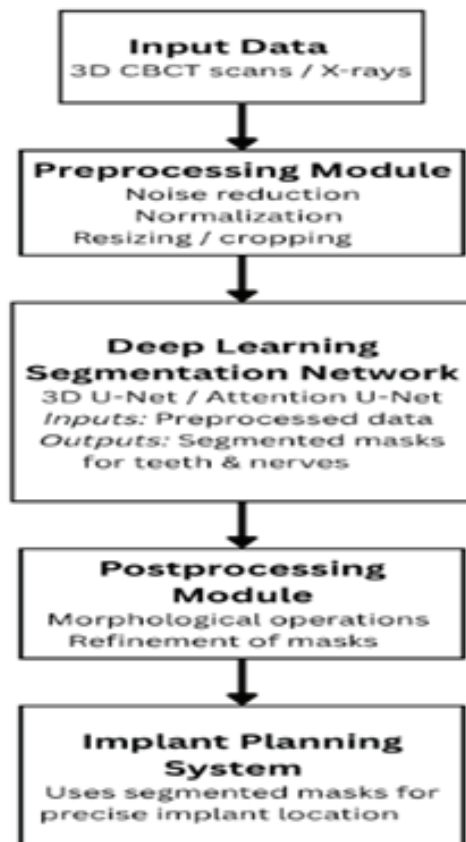
- Segmentation Targets:

The network outputs multi-class segmentation masks where each voxel or pixel is classified as:

- Background
- Tooth structure

- Supports other procedures such as root canal treatment, orthodontics, and maxillofacial surgery.
- Integration:

The segmentation masks can be integrated into surgical navigation systems or CAD/CAM software for implant guides.



ALGORITHM

Network: 3D U-Net

- Input: 3D volumetric image of jaw/teeth (e.g., 128x128x128 voxels).
- Encoder path: Extracts hierarchical features with convolutions and max-pooling.
- Decoder path: Up samples feature maps and merges with encoder features via skip connections for spatial accuracy.
- Output layer: Produces voxel-wise probability maps for teeth and nerve classes.

Loss function:

- Combination of Dice Loss and Cross-Entropy Loss to handle class imbalance and improve segmentation quality.

$$\text{Loss} = \alpha \times \text{Dice Loss} + (1-\alpha) \times \text{Cross Entropy Loss}$$

where α is a balancing weight.

Training steps:

1. Input a batch of preprocessed 3D scans.
2. Forward propagate through 3D U-Net to get predicted segmentation.
3. Compute loss with ground truth labels.
4. Backpropagate gradients and update weights using Adam optimizer.
5. Repeat for multiple epochs until convergence.

RESULTS

Evaluation metrics

- Dice Similarity Coefficient (DSC): evaluates how much the ground truth and anticipated masks overlap.
- Precision and Recall: For nerve and tooth segmentation classes.
- Inference time: For practical clinical use.

Metric	Teeth Segmentation	Nerve Segmentation
Dice Score (DSC)	0.92	0.89
Precision	0.90	0.87
Recall	0.94	0.91
Avg Inference Time (sec)	1.5	1.5

Dice Score Improvement over Training Epochs



The graph shows Dice score steadily increasing during training, stabilizing near 0.9+ by epoch 25, indicating model convergence and good segmentation accuracy.

CONCLUSION

This study presents a DL-based automated system for accurate segmentation of teeth and nerve structures from CBCT scans and dental X-rays. By leveraging advanced convolutional neural network architectures such as 3D U-Net and Attention U-Net, the proposed framework effectively delineates critical anatomical features necessary for precise dental implant planning. The integration of robust preprocessing and postprocessing steps ensures high-quality segmentation masks that facilitate safe implant placement, minimizing the risk of nerve damage. Experimental results demonstrate the system's potential to improve clinical workflow efficiency and implant success rates by providing reliable, automated assistance to dental professionals.

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Campus Guard as EduWatch: An AI-Powered IoT Surveillance Bot for Enhanced Campus Security

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ABSTRACT

Safety at educational campuses has become a critical DNA to maintain the safety and productivity of the learning ecosystem. In this paper we introduce EduWatch: an AI- backed Campus Surveillance Bot to monitor campus and secure students/ staff. Every student deserved a chance to shine. EduWatch uses IoT(Open Source) technologies with Big Data along with Automated patrolling bots, that can be outfitted with cameras, infrared sensors and motion detectors, patrol the campus grounds. Using realtime data processing, it detects suspicious activities and generates alerts for the campus security staff. EduWatch adds a low-light-ready infrared camera for dark areas and advanced image processing methods for better analysis. Early results found that EduWatch exceeded the effectiveness of previous surveillance systems, while not only enhancing campus security but providing an adaptable security solution for schools.

KEYWORDS : *Campus security, IoT, AI, Machine learning, Surveillance, Automated security bots, EduWatch, Public safety.*

INTRODUCTION

Providing a safe environment for students, faculty, and staff is a higher priority than ever for educational institutions. Considering the increase in theft, break-ins, vandalism, trespassing, and even violent acts on campuses worldwide, the conventional solutions of rover guards and CCTV systems are simply not keeping up with the changing nature of campus security threats. Modern campuses has become large and elaborated, they require a constant and alive visual guarding along with a swift and efficient response system. The AI-powered Campus Security Bot, EduWatch aims to bridge these gaps using modern Internet of Things (IoT) technologies combined with machine learning algorithms in a complete holistic solution. The system provides a powerful, self-run, smart solution to institute greater campus security. EduWatch — automated patrol bots with a variety of sensors, including

cameras, infrared sensors, and motion detectors for continuous monitoring of campus sites. The bots are self-driving, so they can reach even the most far-off and at-risk portions of the campus.

One highlight of EduWatch is that it can parsing sensory data in real time. This high-speed analysis allows the system to quickly identify abnormal behavior or security activity that does not belong, responding instantly with campus security teams on the scene proactively rather than waiting for a reactive security response. Using machine learning models to avoid false alarms while still notifying the user only when a valid danger appears. This is a massive upgrade over traditional surveillance systems which usually use manual intervention and do not provide dynamic, contextual detection.

Denim EduWatch also presents a great performance in the various environment such as low illumination environment

and night time environment. Infrared imaging capabilities and image processing algorithms ensures surveillance in light-limited areas remains un-tampered. When identifying a possible threat, the system alerts in real-time with a notification that covers crucial information such as time stamps, activity images, and exact geo-location data, so security personnel can monitor the situation and respond quickly.

We present the design, implementation, and deployment of EduWatch in this paper. We provide details of the hardware and soft-ware, present empirical evaluations of performance, and comment on possible scalability. In summary, EduWatch strives to provide a safer, more secure campus environment for all students, staff, and visitors through the intelligent, effective response to novel challenges confronting campus security in the 21st century.

LITERATURE SURVEY

The EduWatch AI-Powered Campus Security Bot has been developed building upon extensive research in the area of IoT, AI, machine learning, and crime detection. A broader literature review is provided below. The paper describes the crime detection with the help of data mining techniques like k-means & hierarchical clustering, on crime data. Such techniques are used to find patterns and trends in crime that can be re-purposed for detecting anomalies within surveillance data for the campus security system, EduWatch [1]. Crime detection and identification of criminals in surveillance videos using deep learning. Articles by Yash Jain, Abhishek Kumar, Pooja Arora, Springer A CNN based model has been proposed for the real time detection of crimes from surveillance video along with face identification of criminals. Technologies discussed in this paper can implement deep learning in recognizing unauthorized individual (s) on campus in EduWatch[2]. Enhanced Crime Prediction Framework Using Ensemble Learning By Manish Gupta, Snehal Bhise, Rajesh Verma, Elsevier The authors use ensemble learning methods such as Random Forest and AdaBoost for crime prediction. Such algorithms can improve the prediction power of the EduWatch AI system, particularly for identifying possible suspicious activity on campus [3]. An IoT based Real-Time Crime Mapping and Alert System Using Big Data Analytics Authors: Aditi Sharma, Rahul Mehta, ACM Abstract: This paper represent an IoT based system for real-time crime mapping with Big Data analytics. For the design the automated alert system of EduWatch, integration of real-time alert generation through the use of IoT devices is incorporated [4].

IoT Based Hazardous Places Surveillance Robot Authors: T. Akilan, Satyam Chaudhary, Princi Kumari, Utkarsh Pandey, Taylor Francis Abstract: This paper introduces the design and working of a robotic system using IoT technology for hazardous areas and also explains how the controls of Autonomous surveillance bot can be implemented through the help of IoT based services so that we aspire to help assist campus based security implementations [5]. Title: Autonomous Surveillance Robot with Human Detection Phase 1 Authors: A. Dhanashree Tiwari, S. Deepali Keshav Thosar, International Journal of Engineering Research and Applications Abstract The paper here presents the design and implementation of a robotic system which is primarily developed for rescue operation with autonomous navigation phase 3 and human detection features, which are essential to make sure that EduWatch has the operational efficiency to monitor the campus activities [6]. A Framework of Efficient Robot Patrol in Security Application Using Sensor Data and Image Fig 3: Boost and Deliver Internet does the exact same thing as the Sensors and Imaging Processing for most precise surveillance [6].

IJERT Video Surveillance Robot with Multi Mode Operation Authors: Mr. P. Surendra Kumar Mr. V. Venkatesh IJERT Operational Aspects in Wirelessly Controlled Wireless mobility patterns-Cited by 59-Open in a separate window Occasionally (namely 2 3 times per month) Institute of Intelligent Machines and Multimedia, Institut Teknologi Sepuluh Nopember- Similar Bin Rahim, Isozumi 20 based on global arrangement, it always occupied the largest portion of the plan as many different modes can be provided next. Intelligence Video Surveillance: A systematic review of trends, techniques, frameworks, and datasets Authors: Guruh Fajar Shidik, Edi Noersasongko, Adhitya Nugraha, Pulung Nurtantio Andono, Jumanto Jumanto, Edi Jaya Kusuma, IEEE Review on trends and techniques in video surveillance, manually coping with AI and computer vision advances. Such a wide overview gives us methods that can be used in making intelligent features in EduWatch [10].

METHODOLOGY

The methodology for the development of the EduWatch: There are few primary components that are important while developing AI-Powered Campus Security Bot such as objectives, hardware design, and software design.

Objectives

The main purpose of the implemented EduWatch system is the increase of the level of security of the territory of the camp as well as the identification of suspicious and unauthorized actions. Specifically, the system aims to achieve the following objectives:

Real-Time Campus Surveillance: Create a system that will enable it to monitor the college compound during the day and at night.

Early Threat Detection: Report alarms or notices of possible threats or unauthorized activities as soon as possible in order that the campus security authorities can act promptly.

High Accuracy: Maximize the true positive rate and the true negative rate which check the authenticity of the activities and avoid high false positive or false negative values.

Efficient Alert Mechanism: Set up an effective alarm check for the campus security staff to alert them of any threat or intruder, noticed in the vicinity in real-time.

Scalability: Make it also to be expandable horizontally, adaptable for installation in several buildings and outdoors areas of the campus as well as to be integrated into the security system already in use.

User-Friendly Interface: Design an easy to use interface for the members of the campus security staff for supervising and managing the system so that the response time when there is an intrusion is shortened.

In offering these objectives, it is the desire of EduWatch to increase campus security to help protect students, faculty, and staff.

Hardware Design

This paper aims at establishing the various hardware components in the EduWatch system design, which contributes to real-time surveillance and threat identification. Key aspects of the hardware design include:

Surveillance Cameras: Choosing appropriate surveillance cameras with high degrees of definition, as well as low light and infrared detection for round-the-clock security on the campus.

Motion Sensors and Proximity Detectors: Using motion sensors and proximity detectors in order to identify any

unfamiliar movement or attempts at intrusion to some specific sections of the building.

Smart Patrolling Bot: Presence of a smart patrol robot that comes with the under listed features:

IR Sensor: For obstacle and object recognition in front of the robot and in its path.

Ultrasonic Sensor: To need distances and to know when two objects are about to collide or meet.

Bluetooth Module: For the purpose of wireless connection to the central controlling system.

Camera: Incorporation of capture device i.e camera module such as ESP8266 to enable acquisition of real time video clips.

Motors: Control motors for the purpose of allowing movement of the smart patrolling bot.

GPS: GPS for tracking time and location of vehicle.

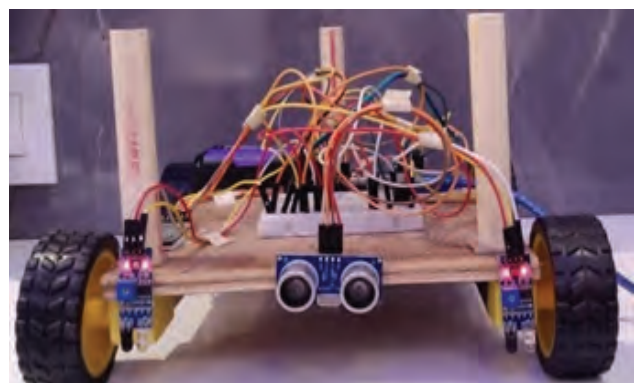
Communication Modules: Connecting it with data modules like SIM800L for data transfer, alarms and interfacing with the campus security.

As with the previous types of design, the principal goal of the hardware design is to support the proper functioning of the EduWatch system in various contexts of the campus.

Software Design

The work on the design of the EduWatch system involves the development of algorithms, programs and interfaces for surveillance, threats identification and alerts. Key components of the software design include:

Image Processing Algorithms: Designing of methods of analyzing images to help in analyzing the video clips recorded by the cameras and the patrolling bot. These algorithms include:

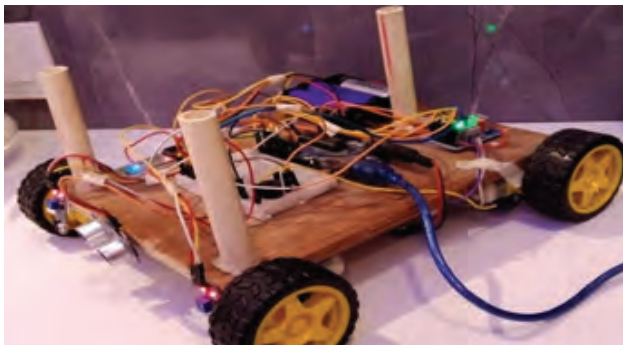


Object Detection and Recognition Algorithms: For purposes of identifying and reporting any strange faces/activities on campus.

Motion Detection Algorithms: In order to prevent unauthorized entry or identified persons from roaming within prohibited areas.

Image Enhancement Algorithms: For enhanced control in conditions of low visibility or in ill-lit areas.

Machine Learning Models: Employment of training and deployment for machine learning models to identify and categories potential threats. Such models take information, which is part labeled datasets that depict usual and unusual activities on campus, to determine the former from the latter.



Central Monitoring System: Implementation of a command center that takes information from the surveillance cameras and the smart moving robot. The monitoring system includes:

User Interface: For campus security personal to have access to real time feeds, alerts and other necessary actions to be taken.

Data Processing Modules: For real time analysis of video footage and to identify possible threats.

Alert Mechanisms: In case of detected threats or any suspicious activity then to alert the campus security.

Integration with IoT Devices: The architectural design of the EduWatch system implies the integration with software capable of establishing proper connections with the IoT devices surveillance cameras and smart patrolling bots in particular and manage data exchange between the system's components.

Email Notification System: Approval of an automated email notification system, which informs the campus

security service of emergent activity observed, with a brief description of the event to be taken by the service.

Utilization of YOLOv3 Model: The EduWatch system utilizes the YOLOv3 (You Only Look Once) model for crime and threat detection. This deep learning-based object detection model enables real-time identification and classification of suspicious activities or individuals with high accuracy and efficiency.

The software design aims to develop a scalable, secure, and adaptable platform for the EduWatch system, capable of handling large.

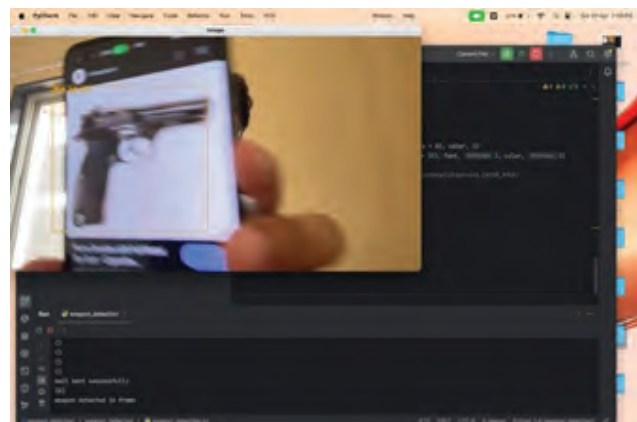


Fig 3: Real-time Crime Detection

Selecting a Template (Heading 2)

Fig. 1: Automated Car

Fig. 2: Automated Car

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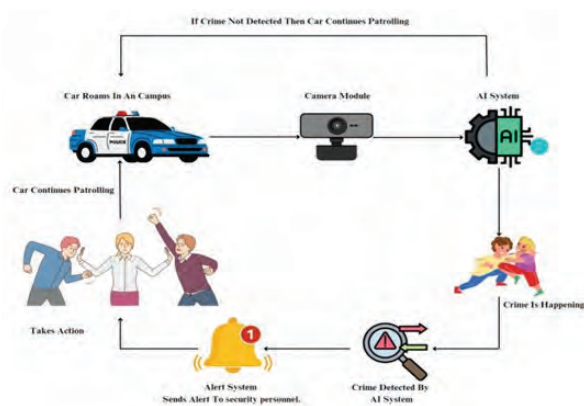
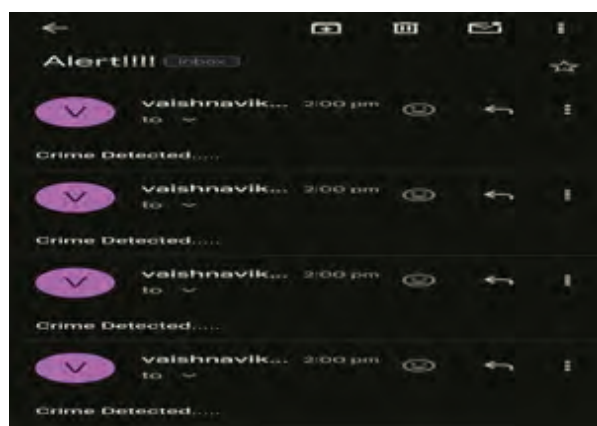


Fig. 5: System Architecture

This paper explains that the data collection and processing phase of the EduWatch system is very vital in identifying and evaluating potential security risks and malicious events both during the day and at night in the campus. In the following section, we view the process of data acquisition and the methods used for the real-time analysis of sensor information.

Data Collection

During surveillance, EduWatch uses cameras among other sensors to collect data on the surrounding environment. The first and foremost 3D sensor is the vision sensor, which captures images or video frames of space. Such images are then analyzed to look for objects of interest; for example, people of interest or activities that are prohibited. EduWatch operates in two modes: Two operational modes are; (1. Autonomous mode whereby the robot moves along specifically marked paths on its own and 2. Manual mode whereby the robot is controlled by members of campus security.) When in the autonomous mode, EduWatch will keep on capturing either the image or frames of the video

as the vehicle moves from one area of the campus to the other. The operator is also given the ability to control manually where EduWatch should observe or how it should react to certain alerts it produces.

Data Processing

After data is collected it is processed in real time in order to identify threats or suspicious activities. The data processing pipeline consists of the following steps:

Preprocessing: The output frames captured from the video or the separate images which are taken for processing are preprocessed to increase their quality and to eliminate as much noise as possible. This may mean scaling, removing noise and/or equalization of data for ease in modeling.

Object Detection: Object detection algorithms used applied on preprocessed image to identify objects of interest like suspect, abnormal activities etc. For real-time object detection, the YOLO (You Only Look Once) algorithm is used in our implementation.

Classification: Having detected objects, they are sorted according to classes which are set in advance. The system is centered on the identification of violators or intruders, however, it can be generalized on identify any abnormality.

Alert Generation: If there are some unauthorized activities or behaviors identified as suspect, the system alarm sounds and informs the campus security for action. Possible messages of the alert are the exact time the activity was noted, the kind of operation recognized, and others delivered by mail or other means.

The data processing pipeline is intended to be real-time to enable the quick reaction by EduWatch to existing security threats or other suspicious events. The results also prove the research methodologies that have been implemented by EduWatch to collect and analyze data for improving and increasing the security of the campus as well as safety of the students, faculty and employees.

Overall, this data collection and processing phase of EduWatch has been found most important and effective for recognizing and monitoring probable security risks in the campus. Through a series of sensors and real time processing algorithms, EduWatch can easily identify the threats and the next thing the campus security will have to do is to act on the identified threats.

Outcomes

The outcomes from implementing EduWatch on campus

include:

Improved Campus Security: The integration of IoT devices and machine learning models significantly enhances campus surveillance.

Accurate Detection: The system's advanced image processing and ML models ensure precise detection of potential threats.

Real-Time Alerts: Real-time alerts provide security personnel with the ability to respond promptly to incidents.

Scalable Deployment: EduWatch can be adapted to campuses of different sizes, making it a versatile security solution.

CONCLUSION

EduWatch represents a major advancement in campus security technology. By integrating IoT devices with AI and machine learning algorithms, EduWatch provides a robust, reliable, and scalable solution for enhancing safety at educational institutions. The system's ability to detect suspicious activities and notify campus security in real-time ensures a secure learning environment for students and staff.

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