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Editorial

Transforming Education Through Tech Age: The educational system has stayed several decades mostly chalkboard and talk classroom method. Teachers enter the classroom and communicates the major source of information, and the learners listen. This is called as either passive or teacher centered education and still in existence in many institutions. Some students will pay attention on lectures and some get bored.

Students are no longer prefer a passive learning, in fact prefer to get involve in active and collaborative learning process using interactive digital boards. Earlier books were scarce and the teachers and students had to go to libraries to collect information. Now, the internet provide access to any kind of information at our fingertips. The traditional classrooms have evolved into a dynamic learning environment where the use of laptops, tablets, Internet of Things (IoT), etc are common. During COVID19 pandemic period, educational institutions were forced to adopt distance learning model. The evolution of new technologies made it possible. Modern technologies and online information have become significant in today's learning environment and will improve the overall quality of education for learners as well as educators.

Technologies makes teaching and learning more accessible, adaptable, and interesting. Technologies have also empowered educators by providing tools and resources for improving their teaching methods and they need training to adopt these new technologies. These new technologies also improve learners' technical knowledge and skills. Also, helpful to access current information more quickly. Digital textbooks provide with latest knowledge while being cost-effective.

The benefits of incorporating new technologies into the learning process include access to a variety of educational resources. Collaboration tools like video conferencing and internet platforms enable students to work together on projects, share ideas, and have productive discussions. It is essential for educational institutions and educators remain updated with these advances and appropriately integrate them in order to provide distinctive and pertinent learning environments for students in the modern era of society. 5.0

Education system must go with new technologies

New Delhi **Editor**

31st December 2024

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A Secure and Effective Blockchain Trust Model for Wireless Sensor IoT

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ABSTRACT

The rapid expansion of blockchain technology in commercial and academic settings has piqued the interest of researchers. Its purpose is to make sure that money transactions are secure and reliable. Subsequently, its applications expanded exponentially. Blockchain is a well-known technology that has several benefits. They include transparency and security. In this study, a trust model and routing protocol are provided as a way to solve these problems for WSIoTs. To determine the shortest path between OSNs and the SN, the authors propose utilising the Dijkstra algorithm as a routing protocol. We eliminate whitespace from the route finding algorithm, providing WSIoTs with a low-cost data storage solution.

KEYWORDS: *Block chain, WSIoT, Dijkstra algorithm, Data storage, OSN.*

INTRODUCTION

The Wireless Sensor Internet of Things (WSIoTs) is based on the widespread deployment of ordinary sensor nodes (OSNs) [1, 2]. In order to compile all of the ONS data, the OSNs transmit it to the central servers. Sink Nodes (SNs) act as relay nodes when it comes to linking OSNs to the main server. Internet of Things (WSIoTs) have several potential applications, including smart city technologies, healthcare, and military use. In order to keep an eye out for various events and collect relevant data, sensor nodes are either fixedly or dynamically placed around a certain area. Some possible issues with WSIoTs include a lack of space for data storage, gaps in coverage, challenges with routing and security, and slow throughput. Furthermore, in WSIoTs, the design of routing protocols is crucial for reliable and effective data transport across the network.

LITERATURE SURVEY

Many protocols, such as geographic routing [3], fuzzy routing [4], transmission adjustment routing [5], etc., have been developed for the best possible route finding. Features like content-centric networking and location-aware services can be provided by geography routing, also known as position-based routing. Moreover, WSIoTs use greedy algorithms to determine the fastest route. Several greedy algorithms and other techniques can be used to find the best course of action, which minimises energy usage while maximising the network's lifespan. Two of the routing problems that WSIoTs face are rapid energy dissipation and the existence of void holes; these problems affect the network's stability. The efficiency of the network is decreased by wasted energy and the gaps that are left after they are filled.

ALGORITHMS

The author addresses the trust model problem by utilising distributed ledger technology, also known as blockchain. The necessity for physical places to store data is rendered obsolete by blockchain technology, as no third party is required to monitor activities or collect fees. Using the Dijkstra algorithm, which finds all possible routes from the source to the SINK node and discards the ones that lead to a VOID, the author was able to decrease energy consumption and avoid the VOID routing issue.

RESULT AND DISCUSSION

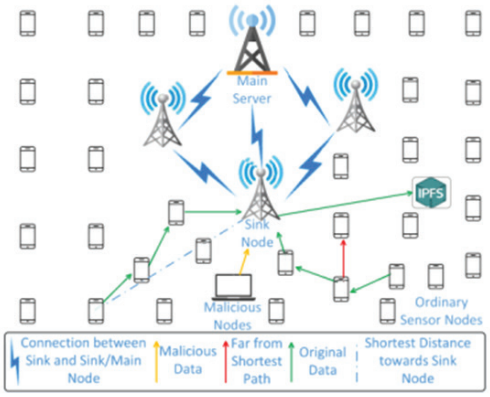


Fig.1. Architecture Diagram

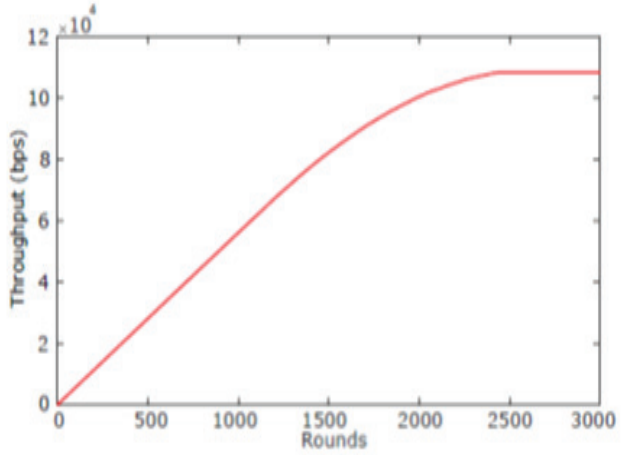


Fig. 2.Click on 'Create IoT Simulation' button to create IOT and get below output

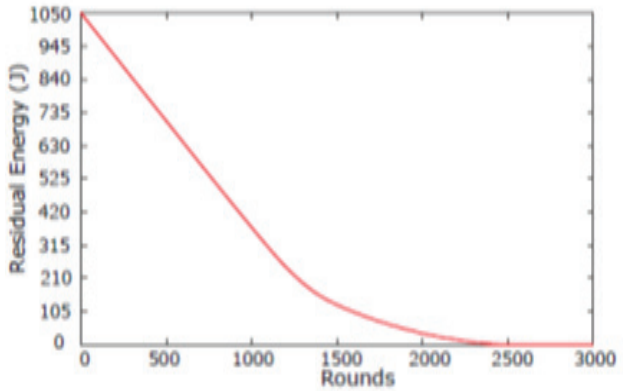


Fig. 3.All red colour circles are normal IOT and blue colour is the Main Server and now click on 'Calculate Sink Node' button to find sink node which is closer to Main Server and get below screen

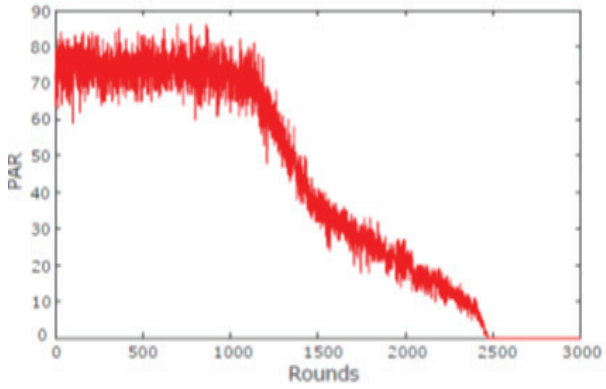


Fig. 4. Click on "Route using Shortest Path" to transmit data to the sink node and main server. The output will be shown below. The green circles indicate the selected sink node, while the huge circle represents all the nodes that are neighbours to each other. You can choose any IoT source from the drop-down box above.

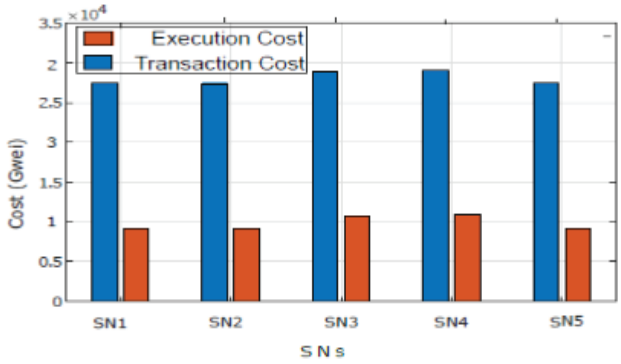


Fig. 5. Selecting 18 as the source node and then click on 'Route using Shortest Path' button to get below output

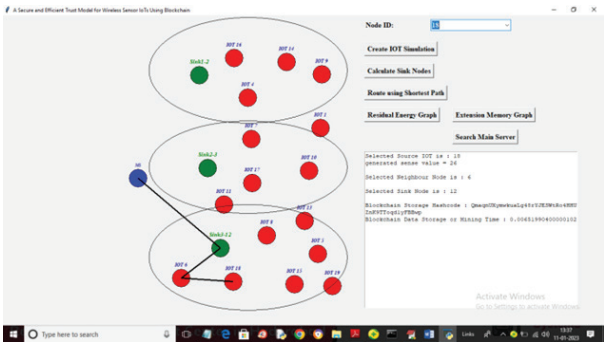


Fig. 6. You can see this path, illustrated by black lines, from source 18 to nearest neighbour IOT 6, which in turn sends data to nearest SINK 3, and finally to the main server. Similarly, you can route data to the main server by selecting the source

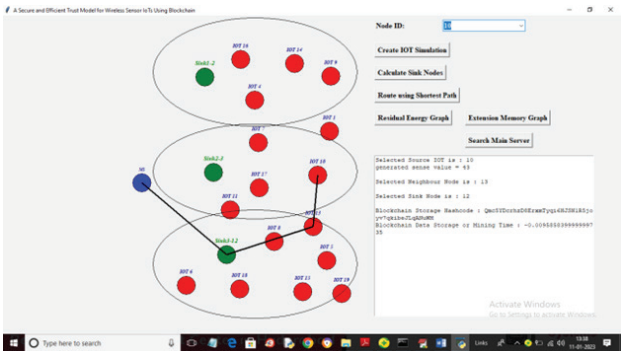


Fig. 7. IOT10 sending data to sink and main server and each random sensing data will store in IPFS and Blockchain

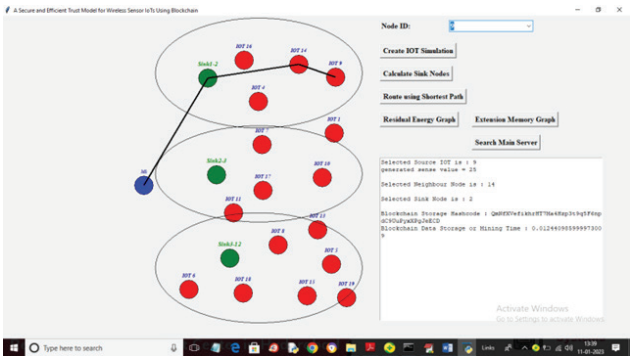
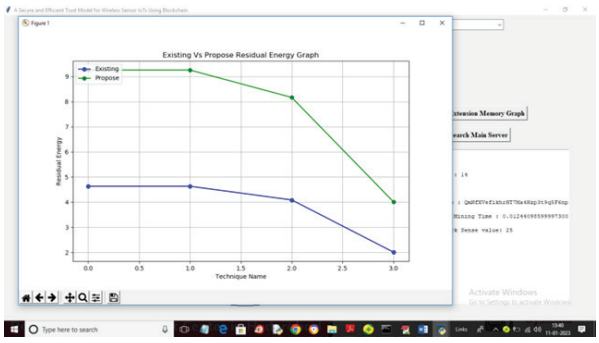
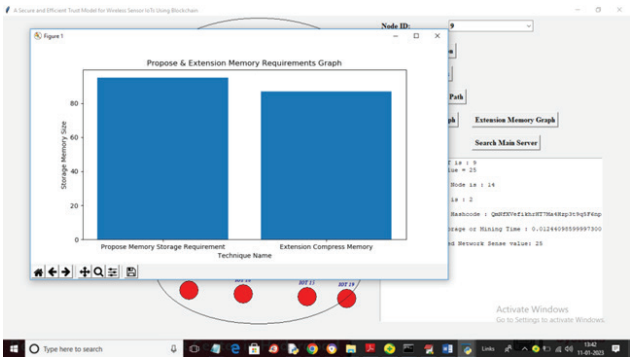


Fig. 8. Source 9 sending data and now click on 'Residual Energy Graph' button to get below output



Graph 1. The available energy using the proposed process is represented by the green line in the above graph, and the available energy using the extension technique is represented by the blue line. The available energy is displayed on the Y-axis, while the number of packets transmitted is displayed on the X-axis. Click the "Extension Memory Graph" button to view the following graph, which illustrates how the suggested work network can lengthen its lifespan and energy availability.



Graph 2. We require more memory for storage with the propose technique, but less memory with the extension compress storage, therefore we can save memory with the extension technique. The X-axis shows the work that has to be done, and the Y-axis reflects the size of the memory requirements. To retrieve IoT data stored in Blockchain and IPFS, choose a source and then hit the "Search Main Server" button.

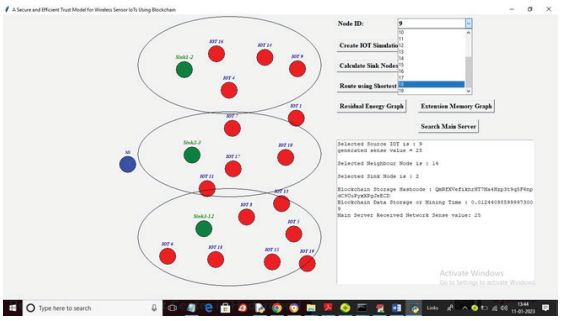


Fig. 9. Selecting source as 18 and then click on 'Search Main Server' to get below output

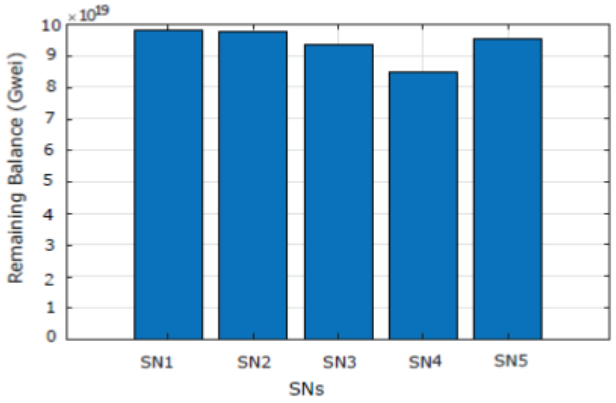


Fig. 10. Following the IOT ID in the first column is the data sensed by the device, followed by a hash code saved in the blockchain, and finally the date and time of the data sensed by the device

You can send data and search server data in a similar way by choosing the source.

CONCLUSION

This work introduces a routing protocol that finds the best route between two locations by combining the Dijkstra algorithm with the formula for the geometric distance between them. By preventing empty spaces from being filled, the proposed algorithm ultimately benefits the network by lowering the power consumption of its nodes. Persistent security is further guaranteed by the trust architecture based on blockchain technology. Because of this, communication between nodes in the network is secure.

REFERENCES

1. N. Javaid, A. Sher, H. Nasir, and N. Guizani, "Intelligence in IoT-based 5G networks: Opportunities and challenges," IEEE Commun. Mag., vol. 56, no. 10, pp. 94–100, Oct. 2018.
2. N. Javaid, "Integration of context awareness in internet of agricultural things," ICT Exp., to be published, doi: 10.1016/j.icte.2021.09.004.
3. K.-V. Nguyen, C.-H. Nguyen, P. Le Nguyen, T. Van Do, and I. Chlamtac, "Energy-efficient routing in the proximity of a complicated hole in wireless sensor networks," Wireless Netw., vol. 27, no. 4, pp. 3073–3089, May 2021.
4. M. Selvi, S. V. N. Santhosh Kumar, S. Ganapathy, A. Ayyanar, H. Khanna Nehemiah, and A. Kannan, "An energy efficient clustered gravitational and fuzzy based routing algorithm in WSNs," Wireless Pers. Commun., vol. 116, no. 1, pp. 61–90, Jan. 2021.
5. N. Javaid, "NADEEM: Neighbor node approaching distinct energyefficient mates for reliable data delivery in underwater WSNs," Trans. Emerg. Telecommun. Technol., p. e3805, Dec. 2019.
6. W. Ali, I. U. Din, A. Almogren, M. Guizani, and M. Zuair, "A lightweight privacy-aware IoT-based metering scheme for smart industrial ecosystems," IEEE Trans. Ind. Informat., vol. 17, no. 9, pp. 6134–6143, Sep. 2021.
7. I. Ullah, N. U. Amin, A. Almogren, M. A. Khan, M. I. Uddin, and Q. Hua, "A lightweight and secured certificate-based proxy signcryption (CB-PS) scheme for E-prescription systems," IEEE Access, vol. 8, pp. 199197–199212, 2020.
8. S. D. Muruganathan, D. C. F. Ma, R. I. Bhasin, and A. O. Fapojuwo, "A centralized energy-efficient routing protocol for wireless sensor networks," IEEE Commun. Mag., vol. 43, no. 3, pp. S8–13, Mar. 2005.
9. P. P. Ray, B. Chowhan, N. Kumar, and A. Almogren, "BIoTHR: Electronic health record servicing scheme in IoT-blockchain ecosystem," IEEE Internet Things J., vol. 8, no. 13, pp. 10857–10872, Jul. 2021.
10. S. Namasudra, G. C. Deka, P. Johri, M. Hosseinpour, and A. H. Gandomi, "The revolution of blockchain: State-of-the-art and research challenges," Arch. Comput. Methods Eng., vol. 28, no. 3, pp. 1497–1515, May 2021.
11. A. Bhardwaj, S. B. H. Shah, A. Shankar, M. Alazab, M. Kumar, and T. R. Gadekallu, "Penetration testing framework for smart contract blockchain," Peer–Peer Netw. Appl., vol. 14, no. 5, pp. 2635–2650, Sep. 2021.
12. M. Allouche, M. Mitrea, A. Moreaux, and S.-K. Kim, "Automatic smart contract generation for internet of media things," ICT Exp., vol. 7, no. 3, pp. 274–277, Sep. 2021.
13. D. Unal, M. Hammoudeh, and M. S. Kiraz, "Policy specification and verification for blockchain and smart contracts in 5G networks," ICT Exp., vol. 6, no. 1, pp. 43–47, Mar. 2020.
14. A. Mateen, J. Tanveer, N. A. Khan, M. Rehman, and N. Javaid, "One step forward: Towards a blockchain based trust model for WSNs," in Proc. 14th Int. Conf. P2P, Parallel, Grid, Cloud Internet Comput. (3PGCIC), 2019, pp. 57–69.
15. G. Ramezan and C. Leung, "A blockchain-based contractual routing protocol for the Internet of Things using smart contracts," Wireless Commun. Mobile Comput., vol. 2018, pp. 1–14, Nov. 2018. 4578 VOLUME 10
16. W. She, Q. Liu, Z. Tian, J.-S. Chen, B. Wang, and W. Liu, "Blockchain trust model for malicious node detection in wireless sensor networks," IEEE Access, vol. 7, pp. 38947–38956, 2019.
17. B. Jia, T. Zhou, W. Li, Z. Liu, and J. Zhang, "A blockchain-based location privacy protection incentive

mechanism in crowd sensing networks,'' Sensors, vol. 18, no. 11, p. 3894, 2018.

18. Z. Rahman, F. Hashim, M. F. A. Rasid, and M. Othman, ''Totally opportunistic routing algorithm (TORA) for underwater wireless sensor network,'' PLoS ONE, vol. 13, no. 6, Jun. 2018, Art. no. e0197087.

19. M. Liu, F. R. Yu, Y. Teng, V. C. M. Leung, and M. Song, ''Computation offloading and content caching in wireless blockchain networks with mobile edge computing,'' IEEE Trans. Veh. Technol., vol. 67, no. 11, pp. 11008–11021, Nov. 2018.

20. Y. Xu, G. Wang, J. Yang, J. Ren, Y. Zhang, and C. Zhang, ''Towards secure network computing services for lightweight clients using blockchain,'' Wireless Commun. Mobile Comput., vol. 2018, pp. 1–12, Nov. 2018.

Secure Data Protection and Retrieval for an Individual Including Comprehensive Data through Aadhar

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ABSTRACT

The "Aadhaar Integration Software" work aims to develop a robust system that consolidates data from four distinct databases: Aadhaar enrollment qualifications, banking information, asset enrollment, and an authentication system. When an Aadhaar number is entered, the software conducts thorough verification and normalization across these databases to generate relevant outputs. To protect sensitive data, the system employs Kerberos authentication, ensuring secure access to database resources. Additionally, normalization and indexing techniques are utilized to enhance database performance, enabling efficient data retrieval and processing. This work marks a significant advancement in data management and security, addressing the diverse needs of government agencies, financial institutions, and other stakeholders. By seamlessly integrating Aadhaar-related data and ensuring compliance with regulatory standards, the software enables organizations to optimize their operations and better serve their constituents while maintaining the privacy and security of sensitive information.

INTRODUCTION

In today's digital landscape, integrating disparate databases into unified systems has become a key driver of innovation, enabling streamlined data retrieval and verification processes. The upcoming software work exemplifies this shift by bringing together Aadhaar enrollment qualifications, banking information, asset enrollment databases, and verification protocols into a cohesive platform designed to transform information management. Built on a solid foundation of research and technological advancements, this initiative represents the intersection of theoretical insights and practical applications, providing innovative solutions to modern challenges in data processing and security.

The frontend of the Aadhaar-based software work provides users with an intuitive interface to initiate verification requests. Utilizing Aadhaar numbers as unique identifiers, users can easily access various services and benefits, such as banking transactions and asset verification. The backend, powered by advanced algorithms and data processing techniques, enables real-time retrieval and validation of information from multiple databases.

Building on the work of Sarje, et al.,[2] this work establishes a foundation for file storage and retrieval using Aadhaar numbers, emphasizing the critical role of unique identifiers in ensuring efficient data management. This aspect of the work requires a systematic approach to organizing information, enabling easy retrieval and verification of records. Sarje, et al., highlight the significance of Aadhaar numbers as key identifiers, facilitating swift access to relevant documents across databases.

El-Emam, et al., [2] enhance the work's security framework with their optimized Kerberos authentication protocol, designed specifically for distributed systems. In a software ecosystem that relies on data from multiple sources, robust authentication mechanisms are essential for preventing unauthorized access and ensuring data integrity. The optimized Kerberos protocol proposed by El-Emam, et al., addresses the challenges of distributed environments, offering a reliable solution for secure communication and access control.

Joshi, et al., [3] offer valuable insights into Kerberos security, shaping the work's efforts to protect sensitive data in distributed environments. Security is a top priority in the design and implementation of the Aadhaar-based software work, given the sensitive nature of the data involved. Joshi, et al.'s analysis of Kerberos security mechanisms highlights potential vulnerabilities and mitigation strategies, guiding the work's approach todata protection and access control.

MeanwhileEl-Hadidi, et al., [4] provide a performance evaluation of the Kerberos protocol, offering insights into optimization techniques to improve the work's scalability and efficiency. In a distributed computing environment, performance optimization is crucial for ensuring seamless user experiences and maximizing resource utilization. By assessing the Kerberos protocol's performance under different workloads and network conditions, El-Hadidi, et al., [4] identify potential bottlenecks and opportunities for optimization.

In conjunction with protection concerns, the assignment emphasizes performance optimization by leveraging insights on data normalization and indexing techniques. By standardizing data codecs and structures, it reduces processing overhead and enhances interoperability between databases. Additionally, the use of indexing mechanisms accelerates record retrieval, ensuring quick response times even for large datasets.

The scope of security goes beyond authentication to include privacy preservation and access control in distributed environments. The effective implementation of privacy measures within the Kerberos framework, as proposed by Fadi Al-Ayed [5] and colleagues [6], highlights the work's dedication to enhancing user confidentiality. By adhering to rigorous privacy protocols and access controls, we ensure compliance with regulatory standards while fostering a culture of trust and accountability among stakeholders.

The work's commitment to continuous improvement and adaptation to changing technological paradigms is emphasized by incorporating insights from Zabel et al.'s [7] study on trends in retrieval system performance. By keeping up with emerging trends and technologies in data retrieval and processing, the work is well-positioned to tackle new challenges and capitalize on emerging opportunities in the digital landscape.

Finally, the work incorporates insights from Neuman et al.'s seminal work on Kerberos [8]: an authentication service for computer networks, which lays the groundwork for implementing robust authentication mechanisms. By integrating this research, the work aligns with established best practices in authentication protocols, thereby enhancing the security and reliability of the system.

In summary, the upcoming software venture represents a blend of technological innovation and practical solutions, set to transform data management and verification. By incorporating insights from a diverse range of research areas and utilizing cutting-edge technologies, the work seeks to unlock new possibilities in efficiency, security, and user experience, establishing a more interconnected and empowered digital ecosystem. Furthermore, the work integrates insights from Losee et al. [9] on information retrieval in distributed databases, which provide analytical models to optimize data retrieval performance. By leveraging these models, the work aims to streamline information retrieval processes, thereby enhancing operational efficiency.

Additionally, the work draws on Allen et al.'s research [10] on perceptual information speed, learning, and retrieval performance, which highlights the perceptual factors that affect information retrieval. By integrating these insights, the work aims to improve user experience and efficiency in accessing information.

Lastly, the work incorporates the research of Subramanian et al. on "Securing Distributed Data Storage and Retrieval in Sensor Networks" and Garay et al.'s work [11] on "Secure Distributed Storage and Retrieval." These studies provide valuable insights into safeguarding data storage and retrieval in distributed systems. By integrating these findings, the work enhances the security and integrity of data throughout the information retrieval process.

In essence, the proposed software work combines academic research with practical innovations, aiming to transform the field of data management and verification. By integrating insights from various research areas and utilizing advanced technologies, the work seeks to establish new benchmarks in efficiency, security, and user experience, ultimately contributing to a more connected and empowered digital ecosystem.

METHODOLOGY

The system establishes a balanced approach that safeguards both individual and societal interests, promoting the responsible use of Aadhar data for the collective benefit and is given in Figure 1.

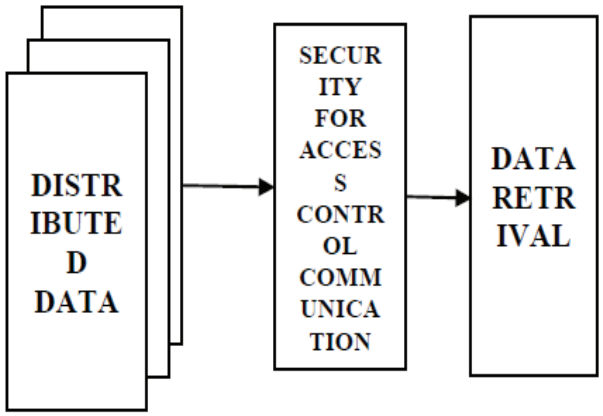

Fig. 1. Block Diagram

Front-End Development

The front-end development process focuses on creating user-friendly interfaces for interacting with integrated databases. HTML, CSS, and JavaScript are used to design responsive web pages that adapt to various screen sizes and devices. A consistent layout and navigation scheme is implemented across all pages to enhance usability. PHP is used for server-side scripting to dynamically generate content based on user input and database queries, while JavaScript ensures data integrity through form validation before submission. AJAX techniques are employed to enable asynchronous data retrieval and updates.

UI/UX Design: We started by conducting thorough research to understand user needs and preferences. Wireframing and prototyping were used to visualize the layout and navigation flow, ensuring an intuitive user experience.HTML Markup: Once the design was finalized, we implemented it using semantic HTML markup to structure web content meaningfully, supporting accessibility and SEO optimization.

CSS Styling: CSS was applied to style and organize the UI components. Responsiveness was prioritized to ensure the interface consistently adapts to different screen sizes.JavaScript Interactivity: JavaScript added interactivity and dynamic behavior, including form validation, DOM manipulation, and asynchronous data fetching to enhance user engagement.

Responsive Design: By leveraging CSS media queries and responsive design principles, we ensured that the application seamlessly adapts to various devices and screen sizes, maintaining a consistent user experience across platforms. AJAX techniques further optimized performance by updating data without reloading the entire page.

REQUIREMENT GATHERING

Aadhaar Enrolment Database:

The Aadhaar Enrolment Database acts as a primary repository of information essential for verifying individuals' identities and enrolment status. The data is collected from multiple sources, such as government enrolment centers, Aadhaar authentication service providers, and demographic data collection agencies. Key fields generally include details like name, address, date of birth, father's name, and enrolment status. To ensure data accuracy and integrity, strong protocols for updating, validating, and synchronizing with central Aadhaar databases maintained by government authorities are crucial.

Asset Database

The Asset Database is divided into two categories: Appreciation Assets and Depreciation Assets. These sections enable the calculation of value increases or decreases from the registration date to the verification date, based on factors and amenities associated with each asset. Appreciation Assets are those whose value rises over time due to factors such as market trends, improvements, or renovations, while Depreciation Assets refer to those that lose value over time due to wear and tear, obsolescence, or other reasons.

The data in the Asset Database is sourced from government registries, asset management agencies, financial institutions, and property registration offices. Key data fields include asset type, ownership details, registration number, purchase date, and valuation information related to appreciation or depreciation. Strong processes for updating asset records and tracking transactions ensure accuracy and timeliness.

Banking Database

By integrating the calculated appreciation and depreciation amounts from the Asset Database, the Banking Database updates individual account balances accordingly. Appreciation reflects an increase in asset value over a specified period, while depreciation represents a decline. These adjustments are applied to account balances based on transactions linked to asset value changes.

The data in the Banking Database comes from financial institutions such as banks, credit unions, and service providers. In addition to standard fields like account number, type, and balance, extra fields are included to capture asset-related transactions. To ensure confidentiality and data integrity, the system employs robust security measures such as encryption, access controls, and audit trails

Qualification Database

The Qualification Database consolidates information related to individuals' educational achievements, certifications, and professional milestones. Key data sources include educational institutions, certification bodies, professional associations, and training organizations. Typical data fields cover qualification type, institution attended, degree earned, certification grade, and year of completion. Due to the importance of educational credentials, implementing reliable verification methods—such as degree validation services, certification checks, and accreditation confirmation—is crucial to ensuring the authenticity and accuracy of the data.

DATABASE INTEGRATION

In this system, the focus is on seamlessly integrating data from multiple databases. The process begins by identifying databases containing relevant information, such as Aadhaar enrolment, qualifications, banking, and asset registration. Using PHP's database connectivity features, establish connections to each database. SQL queries are employed to retrieve the required data based on the Aadhaar number provided by the user. To optimize retrieval, indexing is applied to frequently searched columns, such as the Aadhaar number. Databases are normalized to third normal form (3NF) to reduce redundancy and maintain data integrity, breaking tables into smaller entities and establishing relationships between them. Joins and unions are then used to combine data from different databases into a unified format for verification.

Normalization

Normalization techniques are crucial for organizing databases efficiently, reducing redundancy, and improving data consistency. Understanding normalization stages, such as First, Second, and Third Normal Form, is key to optimizing database design. By breaking down data into smaller, more manageable tables and eliminating data dependencies, normalization enhances data integrity, minimizes duplication, and simplifies maintenance.

In 3NF, entities like Asset Value and Current Balance are identified, and attributes such as asset type and account balance are separated. Tables are decomposed to avoid redundancy, and relationships are created using foreign keys, linking assets to their appreciation/depreciation details and connecting transactions to relevant accounts. This ensures an efficient structure and preserves data integrity.

Indexing

Indexing is essential for enhancing query performance and speeding up data retrieval operations. Different types of indexes, such as B-tree indexes, hash indexes, and bitmap indexes, address various data access patterns and query needs. Implementing and maintaining effective indexing strategies are crucial for optimal database performance. It is important to carefully select columns for indexing based on query patterns, data distribution, and access frequencies to maximize the benefits of indexing while minimizing overhead and storage demands.

KERBEROS AUTHENTICATION INTEGRATION

Kerberos authentication is essential for securing access to integrated databases. The process starts with configuring the Kerberos server and establishing trust relationships within the network to ensure reliable access. The Kerberos authentication protocol is then implemented to verify user identities before granting access to the system. PHP's Kerberos extension is

used to handle authentication requests and validate user credentials against the Kerberos Key Distribution Center (KDC). Security is further enhanced by encrypting communication channels between the client, server, and KDC using encryption algorithms supported by Kerberos.

DISCUSSIONS AND RESULTS

The proposed work has been secured using the Kerberos authentication algorithm. The analysis involved evaluating query retrieval times across 10 cases. This testing was performed on a 1.19 GHz Intel® Core™ i5-1035G1 CPU with 8GB of RAM running Microsoft Windows 10 20H2. All functionalities of the web application were developed using Visual Studio Code 6.0.

Figure 2 illustrates the input datasets sourced from four distinct databases: Banking, Qualification, Asset, and Aadhaar enrolment.

Fig. 2 :Database inputs

The output image shown in Figure 3 represents the verification page, which displays consolidated data from all the databases.

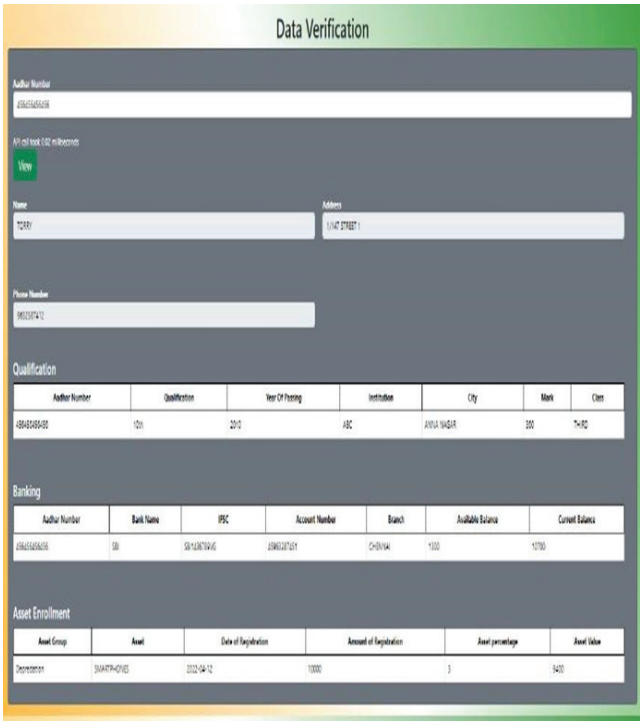

Fig. 3: Verification page

This succeeding table Table1 compares query performance before and after implementing indexing strategies.

Table 1: Indexing Performance Analysis

Query Type	Average Response Time Before Indexing (s)	Average Response Time After Indexing (s)	Improvement (%)
Aadhaar Lookup	1.2	0.3	75
Banking Details Retrieval	0.9	0.4	55
Asset Details Retrieval	1.0	0.5	50
Qualification Details View	0.8	0.3	62

This following table 2 compares the normalization performance before and after implementation.

Table 2: Normalization Efficiency

Normalization Type	Attributes before normalization (s)	Attributes before normalization (s)
4NF	Aadhar number in bank Aadhar number in aadhar enrollment Aadhar number in asset enrollment Aadhar number in qualification	Single attribute called aadhar number is used. (multi valued dependency)
1NF	Login and username can be duplication.	Duplication is removed.

The succeeding table 3 and table4 shows the efficiency of data retrieval by using the query retrieval time, considering all indexing and normalization measures.

Table 3: Data Retrieval Efficiency

Data Type	Retrieval Method	Normalized	Indexed	Average Retrieval Time (s)
Aadhaar Details	Direct	Yes	Yes	0.3
Banking Details	Direct	Yes	Yes	0.4
Asset Details	Join	Yes	Yes	0.5
Qualification Details	Join	Yes	Yes	0.3

Table 4: Query Request Time

CASE NUMBER	QUERY RETRIEVAL TIME(milliseconds)
Case 1	0.019
Case 2	0.031
Case 3	0.022
Case 4	1.599
Case 5	0.571
Case 6	0.018
Case 7	0.007
Case 8	0.015
Case 9	0.013
Case 10	0.024
$\overline{T}$	0.2319

The resulting average for retrieving the data from the database( ) was calculated by the following formula:

$$\overline{T} = \frac{1}{n}\sum_{i=1}^{n} T_i$$

Where,

- $\overline{T}$ is the average retrieval time.
- Ti represents the retrieval time for each individual case, with i ranging from 1 to n.
- n is the total number of cases

This equation expresses the sum of all retrieval times (Ti) divided by the total number of cases (n), which yields the average retrieval time. By employing indexing techniques in the database, the retrieval time has been reduced to 0.23 milliseconds.

CONCLUSION

In conclusion, the "Aadhaar Integration Software" work represents a major step forward in data management and security. By consolidating information from Aadhaar enrollment, qualifications, banking, and asset databases, the system provides a unified platform for comprehensive data verification and processing. The implementation of Kerberos authentication ensures robust security measures, protecting sensitive information from unauthorized access. Through effective use of normalization and indexing techniques, the software enhances database performance, enabling rapid and accurate data retrieval.

This paper addresses the complex needs of various stakeholders, including government agencies and financial institutions, by streamlining data integration and ensuring compliance with regulatory standards. Ultimately, it improves operational efficiency and service delivery while maintaining the highest standards of privacy and data security.

REFERENCES

1. Abhishek Sarje, Shashikant Pattewar, Abhijit Pawar, Saurabh Nimse, " Document Storage and retrieval

Using Adhaar Number"(2018) , Volume 3,Issue 1,pp. 4991-4993, 2018 ISSN 2395-1621.

2. Eman El-Emam, Magdy Koutb, HamdyKelash, and Osama Farag Allah, "An Optimized Kerberos authentication Protocol".
3. Pratik Joshi, Stevens, "Kerberos Security in distributed Systems"(2022),Volume9, Issue 2, e-ISSN: 2395-0056, p-ISSN: 2395-0072.
4. Mahmoud T. El-Hadidi, Dr. Nadia H. Hegazi, HebaK. Aslan, "Performance Analysis of the Kerberos protocol in a Distributed Environment".
5. Graham Bent, Dominic Harries, Andrew J. Toth,"Extending the Kerberos Protocol for Distributed Data as a Service "(2012).
6. Justin Zobel, Hugh Williams, "Trends in retrieval System performance"(2000), DOI:10.1109/ ACSC.2000.824410.
7. Fadi Al-Ayed, Chunqiang Hu and Hang Liu, "An Ecient Practice of Privacy Implementation: Kerberosand Markov Chain to Secure File Transfer Sessions"(2017), DOI: 10.6633/IJNS.20180720(4).07.
8. B. Clifford Neuman, TheodoreTs'o, Kerberos: An Authentication Service for Computer Networks"(1994), Volume 32.
9. Robert M. Losee , Lewis Church Jr, " Information retrieval with Distributed Databases: Analytic models of Performance"(2003), Volume. 14, Issue 12.
10. Bryce Allen," Perceptual Information Although Speed, Learning and Retrieval Performance".
11. Nalin Subramanian, Chanjun Yang, and Wenshengzhang," Securing Distributed Data Storage and retrieval in Sensor Networks".
12. Juan A.Garayy, Rosario Gennaroz, Charanjit Jutlaz, Tal Rabinz," Secure Distributed storage and Retrieval".

Online Blockchain based Certificate Validation System for Government Organization

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ABSTRACT

The increasing demand for secure and tamper-proof certificate validation has led to the development of blockchain-based frameworks. This paper presents an online blockchain- based framework for certificate validation, leveraging the immutable and decentralized nature of blockchain technology to enhance the security, transparency, and efficiency of the validation process. The proposed framework employs smart contracts to automate the issuance, storage, and verification of certificates, ensuring their immutability and facilitating third- party verification. By utilizing a decentralized ledger, the frame- work mitigates the risk of certificate forgery and unauthorized alterations. Furthermore, it provides a user-friendly interface for stakeholders, including certificate issuers, recipients, and verifiers, to interact seamlessly with the system. Applicable in various domains such as education, professional certification, and compliance, this framework offers a robust solution to the growing challenges in certificate validation. This paper discusses the architecture, implementation, and potential benefits of the proposed framework, supported by a case study demonstrating its practical application.

KEYWORDS: *Certificate, Hash, IPFS, Solidity, Smart contract.*

INTRODUCTION

Academic and educational certificates are essential indicators of an individual's human capital, encompassing skills, competencies, aptitude, and knowledge. These certificates are crucial for employment as they validate a candidate's qualifications, thus ensuring their suitability for specific roles. However, the significant value attributed to these certificates has led to widespread issues of forgery and misrepresentation. Fake academic certificates, which can closely mimic genuine ones, are generated through various means such as fabricated documents, degree mills, and modified records [1]. This proliferation of counterfeit certificates poses serious challenges, necessitating robust verification mechanisms.

Blockchain technology, with its inherent characteristics of decentralization, transparency, and immutability [2], presents a promising solution for enhancing the certificate verification process. By leveraging blockchain, we can establish a secure, tamper-proof system that eliminates the need for intermediaries, reduces costs, and ensures that only authorized individuals can access the stored data.

In our research, we have developed an online blockchain- based framework for certificate validation. This framework involves three key stakeholders: the admin (government), who oversees and manages the system; the issuer (college), who generates and issues certificates; and the validator (anyone), who can independently verify the authenticity of these certificates. By utilizing hashing algorithms our system computes and stores hashes on the blockchain. Verification of both the student and their certificate is achieved by matching these hashes, ensuring the integrity and authenticity of the credentials.

The major contributions of our research include the implementation of educational certificate verification using the Ethereum blockchain[3], enhanced security

through the integration of hashing algorithms [4], and the establishment of a robust link between the student and their certificate. This paper outlines the architecture, implementation, and potential impact of our blockchain-based certificate validation framework.

LITERATURE SURVEY

Educational certificates are essential for higher education and job applications, but they are often targeted by forgers. Traditional methods like signatures, stamps, and seals [5] are commonly used but are easily replicated. Blockchain technology, particularly Ethereum, offers a more secure approach to certificate validation, ensuring data integrity and transparency. Once data is recorded on the blockchain, it cannot be altered or deleted, and its decentralized nature [6] protects against attacks and outages, as data is distributed across multiple nodes.

Cryptocertify [7] introduces a central authority (admin and university) to guarantee trust. However, it uses the SHA-3 algorithm, which can be slower than SHA-2 due to its complex structure, leading to computational overhead.

The University of Liberal Arts Bangladesh [8] uses Content Identifiers (CIDs) to store certificates on IPFS, but the CID allows anyone to access the certificate, raising privacy concerns.

Certifier DApp [9] uses uuidv4 to generate certificate IDs but lacks oversight from an authoritative body, which diminishes trust in the certificates' authenticity. While uuidv4 reduces the likelihood of ID collisions, the absence of a governing body raises concerns about certificate issuance, allowing potential misuse and altering of certificate details without regulation.

The decentralized application (DApp) developed by Nishant et al. [10] restricts administrative control to the smart contract deployer, limiting system flexibility. Furthermore, the certificate ID is accessible, which poses a risk of unauthorized access.

E-Certify [11], developed by students at Nitte University, creates unique certificate IDs and transaction hashes but lacks a robust verification system, making it vulnerable to misuse.

SJCET students [12] designed a verification system that allows only the smart contract owner to authorize institutions and uses transaction IDs for verification. This poses risks, as the transaction ID can be compromised. Additionally, SHA- 256, the algorithm used, is vulnerable to lookup table attacks, where precomputed tables of hash values are used to uncover plaintext passwords.

Research Gap

- Use of vulnerable hashing algorithms: SHA-256 and SHA-3 are used to generate certificate hashes or unique IDs, but they are vulnerable to lookup table attacks. These tables contain precomputed hash values from common passwords, allowing attackers to match compromised hashes and uncover the original plaintext.
- Absence of centralized authorities: Without trusted entities like universities, colleges, or government personnel overseeing certificate validation, there is distrust in the process. Unqualified authorities, such as random smart contract deployers, can lead to unreliable validation.
- Cloud storage: Some studies highlighted the lack of decentralized cloud storage, like IPFS, for storing physical certificate images. This absence hinders image comparison during verification and prevents data backup in case of blockchain data loss.
- Using Content Identifiers (CIDs)/Certificate ID's for cross-verification: Many projects use specific IDs for certificate identification and verification. However, these IDs can be compromised by malicious parties, allowing certificate tampering.

Strategies employed for overcoming the research gaps identified in the aforementioned studies

- Use of PBKDF2-SHA256 hashing algorithm: PBKDF2- SHA256 uses key stretching and salts to enhance security. A salt, a random text added to the original value, obscures the password, making attacks like lookup and rainbow tables ineffective due to the salt's uniqueness for each user.
- Presence of centralized authorities for issuing of certificates: The involvement of trusted institutions like universities, accredited colleges, and government personnel in the validation framework

ensures reliability and credibility, enhancing confidence in the authenticity of issued certificates.

- Use of InterPlanetary File System (IPFS): The InterPlanetary File System (IPFS) is used for decentralized storage of certificate images. During verification, the provided image is compared with the IPFS-stored version. IPFS also serves as a backup in case of data loss on the blockchain.
- Comparison of physical certificates: The input certificate is compared with the IPFS-stored version for validation, eliminating the need for unique IDs that could be leaked.

The remainder of the paper is organized as follows: Section 4 presents the results and findings derived from comprehensive research and implementation. Section 5 offers the future scope, followed by a discussion of the conclusion of the solution provided.

PROPOSED METHODOLOGY

The objective of this research is to design and implement a secure, decentralized system for document storage and verification. This system leverages blockchain technology for security and the InterPlanetary File System (IPFS) for decentralized storage, complemented by PBKDF2 (Password Based Key Derivation Function 2) with SHA-256 hashing algorithms for data integrity. Key project considerations include:

- Only government authorities (admins) have the authority to grant access to educational institutions for issuing certificates.
- Implementation of automation through smart contracts ensures efficiency and transparency [13].
- The platform is designed to be decentralized, accessible across various testnets to facilitate testing and scalability.
- Verification functionality is accessible to all stakeholders, including students, teachers, and other relevant parties.

The workflow takes place in the following manner:

Registration Process

Fig. 1 depicts the working of the registration process. Users begin by connecting their Web3 wallet to the website. The wallet's address is used for transactions and registration purposes. If the user doesn't have a Web3 wallet, they are guided to install the necessary browser extension. Users are categorized as follows:

- Admin: A Government personnel is responsible for managing access rights in the admin section. Admins authorize colleges by providing their wallet address and college name for access to upload certificates onto the blockchain.
- College: Once authorized by the admin, colleges can securely upload their specific certificates onto the blockchain. This ensures that certificates are tamper-proof and accessible for verification.
- Validator: Stakeholders such as students can verify their documents by selecting the file, uploading it for verification, and receiving instant results to confirm the validity of the certificate.

Uploading Process

As shown in Fig. 2, the system first verifies whether the college attempting to upload a certificate is registered and authorized by the admin. This verification is done by cross- referencing the college's MetaMask wallet address with data from the blockchain.

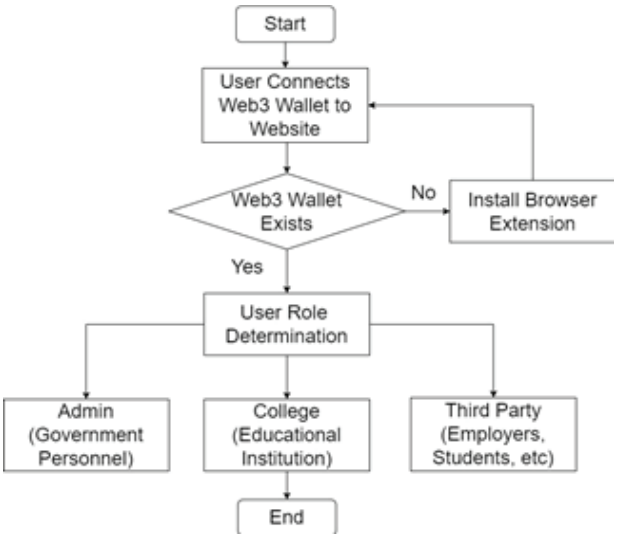

Fig. 1. Registration Process

After verification, the student's account address and the file to be uploaded are input. The file's base64 (b64) [14] format is hashed using PBKDF2 with the SHA-256 algorithm, and the hash is stored on the blockchain. The

physical file is stored on the InterPlanetary File System (IPFS) [15] using Pin˜ata Cloud, a service that generates a unique IPFS hash for the file, ensuring decentralized storage and retrieval.

The IPFS hash is mapped to the PBKDF2-SHA256 hash generated from the file's b64 format using a smart contract, and this hash is linked to the student's address. The first mapping ensures efficient and secure file verification, while the second mapping prevents unauthorized access, ensuring only the student can download the certificate.

The PBKDF2-SHA256 hash serves as a digital fingerprint stored on the blockchain, providing tamper-detection since any file modification would alter the hash. Blockchain technology ensures an immutable record of the file's hash, adding a layer of security.

Users are prompted to pay a gas fee, compensating network validators for processing transactions. By combining IPFS, blockchain, and Pin˜ata Cloud's API, the system ensures secure, verifiable, and tamper-proof document storage.

Verification Process

The verification process operates without admin authorization, allowing all users to verify certificates. Users select a file, which is hashed in base64 format using PBKDF2- SHA256, providing enhanced security through a salt and multiple iterations. The generated hash is cross-referenced with the blockchain-stored hash. If they match, the certificate is confirmed as valid.

Next, the Pinata Cloud image hash is retrieved using the PBKDF2-SHA256 hash mapping, and the image is fetched and displayed. As shown in Fig. 3, this integration ensures secure, user-friendly verification by leveraging PBKDF2-SHA256 and blockchain technology.

Downloading Process

As shown in Fig. 4, the download section is accessible only to students whose account addresses are mapped to the PBKDF2-SHA256 hash generated from the certificate's base64 format during upload. This ensures only the student can download the image, preventing third-party access and tampering.

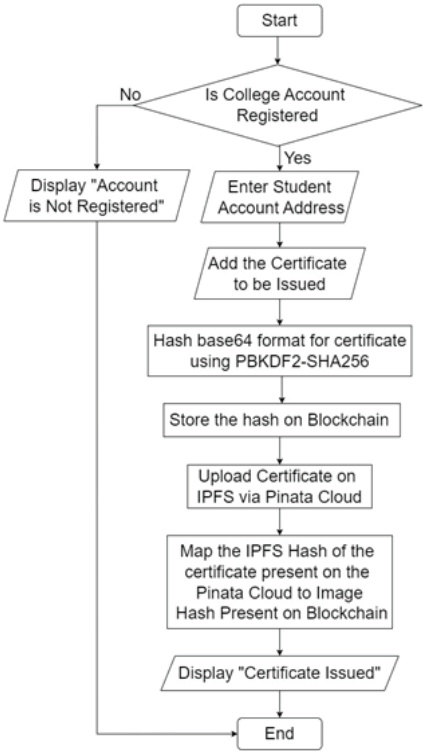

Fig. 2. Uploading Process

RESULTS

Comparison Between PBKDF2-SHA256 and SHA-256

To provide real-time data-based readings for the comparison between PBKDF2-SHA256 and SHA-256, we can simulate a series of tests that measure performance in terms of time taken for various operations. These operations include the resistance of PBKDF2-SHA-256 and SHA-256 against brute force attacks.

Initially, let us calculate the average hashing time for both algorithms over a set iterations:

- SHA-256 with average of 1,000 readings
- PBKDF2-SHA256 with average of 100 readings over 1,000 iterations
- PBKDF2-SHA256 with average of 100 readings over 100,000 iterations.

Table I represents the results of the time measurements for hashing a password using SHA-256 and PBKDF2-SHA256 with different iteration counts:

Now, we can estimate the brute force time required based on the average hashing times obtained. Assuming a 6-character alphanumeric password, the total number of combinations is:

36^6 = 2, 176, 782, 336 (1)

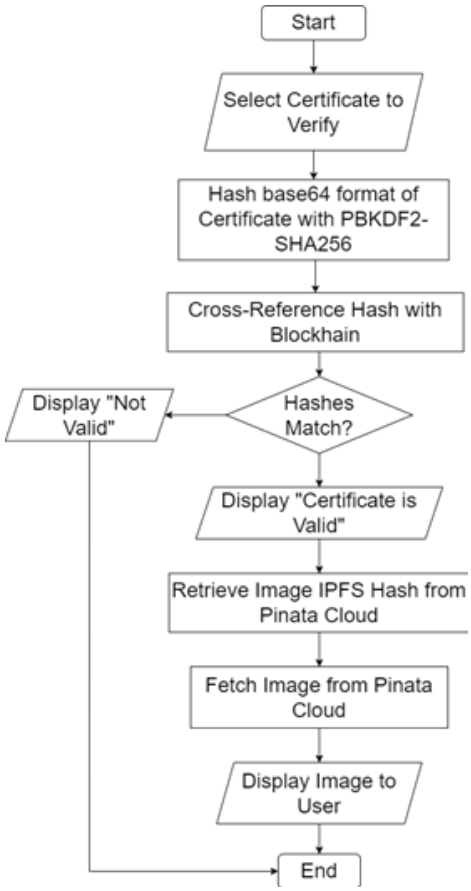

Fig. 3. Verification Process

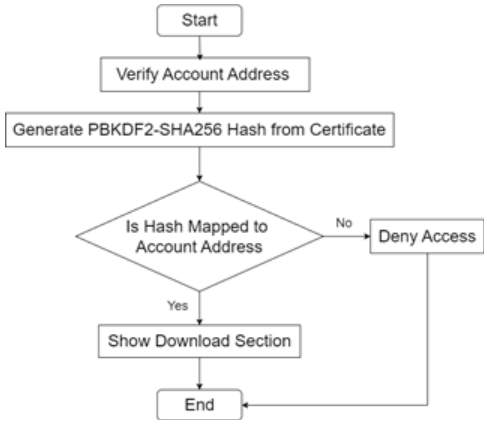

Fig. 4. Downloading Process

Table 1 Average Hashing Time of PBKDF2-SHA256 VS SHA-256

Algorithm	Readings	Avg Hashing Time (sec)
SHA-256	1,000	0.001076
PBKDF2-SHA256 (1,000 iterations)	100	0.099818
PBKDF2-SHA256 (100,000 iterations)	100	10.484087

Estimated Brute Force Time Calculations

• SHA-256:

TotalCombinations * AverageHashingTime (2)

• PBKDF2-SHA256 (1,000 iterations):

TotalCombinations * AverageHashingTime (3)

• PBKDF2-SHA256 (100,000 iterations):

TotalCombinations * AverageHashingTime (4)

Estimated Brute Force Attack Times

Here are the estimated times required to brute force a 6-character alphanumeric password:

• SHA-256: Approximately 2,342,218 seconds (27 days)

• PBKDF2-SHA256 (1,000 iterations): Approximately 217,282,059 seconds (6.9 years)

•PBKDF2-SHA256 (100,000 iterations): Approximately 22,821,575,391 seconds (723.7 years)

Table 2 Brute Force Attack Time Calculations

Algorithm	Iterations	Avg Hashing Time (sec)	Estimated Brute Force Time (sec)	Estimated Brute Force Time (years)
SHA-256	N/A	0.001076	2,342,218	0.0739726
PBKDF2-SHA256	1,000	0.099818	217,282,059	6.9
PBKDF2-SHA256	100,000	10.484087	22,821,575,391	723.7

Table 3 Sepolia vs Other Testnets

Operation	Sepolia Gas Used	Ropsten Gas Used	Goerli Gas Used
Deploy Contract	~1,500,000	~1,800,000	~1,600,000
setInfo	~50,000	~55,000	~52,000
Function setImageHash Function	~80,000	~90,000	~85,000

The results in Table II clearly illustrate the significant increase in brute force resistance provided by PBKDF2-SHA256 compared to SHA-256. The higher iteration count in PBKDF2-SHA256 dramatically increases the time required to brute force a password, thereby enhancing security against such attacks. This demonstrates the advantage of using PBKDF2- SHA256 for secure password hashing.

Sepolia Testnet Readings

Sepolia is one of Ethereum's newer testnets [16], designed to provide a stable and efficient environment for developers to test their smart contracts. Here are some advantages of using Sepolia over other testnets, along with relevant readings to support these points:

Stability and Longevity

- Sepolia is designed to be a long-term testnet, unlike some older testnets that may be deprecated or unstable.
- It is actively maintained, ensuring compatibility with the latest Ethereum upgrades and features.

Reduced Congestion:

- Sepolia typically experiences less congestion compared to more popular testnets like Rinkeby [17] or Ropsten [18], resulting in faster transaction confirmation times.
- Lower network congestion can lead to more consistent and predictable gas fees.

Enhanced Security

- Sepolia incorporates the latest security features and improvements from the Ethereum mainnet.
- Its design aims to provide a more secure environment for testing compared to older testnets that might not include recent security updates.

To illustrate these advantages, we can compare gas fee readings for common operations on Sepolia and another testnet, such as Ropsten and Goerli. For this purpose, we deploy our smart contract on Sepolia, Ropsten, and Goerli using tools like Hardhat, Remix, or Truffle. By measuring the gas used for each operation through transaction receipts or gas estimators provided by these platforms as shown in Table III, we obtained the following results:

By comparing gas fees across Sepolia, Ropsten, and Goerli, it is evident from that Sepolia generally offers lower and more consistent gas fees, reduced network congestion, and enhanced resource efficiency. These advantages make Sepolia an attractive choice for a certificate validation framework, especially where frequent operations on the blockchain are required.

With VS Without Encryption

In our experiment, we compared the performance of data retrieval from a smart contract with and without encryption using PBKDF2-SHA256. The following test cases are considered:

Encryption Process:

- Password-based key derivation function 2 (PBKDF2) with SHA-256 was used to generate the encryption key.
- Data retrieval times were measured for both encrypted and unencrypted data.

Data Retrieval Simulations

- Simulated retrieval of unencrypted data.
- Simulated retrieval of encrypted data.

Performance Measurements:

- The time taken for each retrieval operation was measured in seconds.
- 1000 iterations were performed for both encrypted and unencrypted retrievals to gather sufficient data for analysis.

The following data was obtained after performing the above test cases:

Table 4 Data Retrieval With and Without Encryption

Iteration Number	Time Without Encryption (sec)	Time With Encryption (sec)
1	0.0000082	0.0021605
2	0.0000021	0.0018392
1,000	0.000002	0.0018357

The analysis formulated in Table IV shows that while encryption introduces a slight overhead to block retrieval times, this impact is minimal. This indicates that the encryption method used is efficient and does not significantly degrade the system's overall performance. Therefore, PBKDF2-SHA256 can be effectively employed in smart contract applications to enhance data security.

FUTURE SCOPE

Future upgrades for the certificate validation DApp aim to enhance functionality and security:

Introduction of secret passphrases for download section:

- A salt [19] used during certificate hashing can act as a secret passphrase, sent to the student. The student must enter this passphrase to download their certificate, ensuring only the intended recipient can access it.

Integration of Government IDs:

- Educational institutions can store a student's government ID (e.g., Aadhar) on the blockchain, linking it to their account address. This ensures only legitimate students receive certificates, reducing fraud.

By pursuing these upgrades, the certificate validation DApp can continue to evolve, offering greater value and a more comprehensive solution for certificate management and validation. These enhancements will not only improve the DApp's performance and security but also expand its reach and impact, making it a valuable tool for users worldwide.

CONCLUSION

The rise of counterfeit academic certificates threatens the integrity of the educational system. Our research tackles this issue by using blockchain technology to create a decentralized, transparent, and immutable certificate validation framework. This secure system reduces the risk of forgery by involving key stakeholders: the government as admin, educational institutions as issuers, and the public as independent validators, ensuring only legitimate credentials are verified. The integration of robust hashing algorithms like PBKDF2-SHA256 which is iterated in order to further fortify the hashed string [20] further enhances security, creating an unbreakable link between the student and their certificate. This approach not only simplifies the verification process but also significantly reduces the costs and complexities associated with traditional methods.

Our blockchain-based framework secures the authenticity of academic certificates, reinforcing trust in educational qualifications and maintaining the credibility of human capital indicators. Its architecture and implementation highlight its potential to revolutionize certificate verification, setting a new standard for managing and authenticating credentials in the digital age.

REFERENCES

1. Grolleau, Gilles and Lakhal, and Mzoughi, Naoufel. (2008). "An Introduction to the Economics of Fake Degrees." Journal of Economic Issues. vol. 42., pp. 673-693., doi: 10.1080/00213624.2008.11507173.

2. Z. Zheng, S. Xie, H. Dai, X. Chen and H. Wang, "An Overview of Blockchain Technology: Architecture, Consensus, and Future Trends," 2017 IEEE International Congress on Big Data (BigData Congress), Honolulu, HI, USA, 2017, pp. 557-564, doi: 10.1109/BigDataCongress.2017.85.

3. M. Staderini, A. Pataricza, and A. Bondavalli, "Security Evaluation and Improvement of Solidity Smart Contracts," Journal of Systems and Software, 2022. [Online]. Available: https://ssrn.com/abstract=4038087.

4. N. A. A. Mustafa, "Analysis attackers' methods with hashing secure password using CSPRNG and PBKDF2," ejuow, vol. 12, no. 2, pp. 60–70, Apr. 2024, doi: 10.31185/ejuow.Vol12.Iss2.502.

5. Isizoh, A.N., Anyi, D.O., Onyeyili, T.C., Ebih, U.J., and Ejimofor, I.A. (2021). "Certificate Fraud Detection Using Artificial Intelligence Technique". International Journal of Research Publication and Reviews, vol. 2, no. 11, pp 801-818.

6. Zheng, Z., Xie, S., Dai, H.-N., Chen, X., and Wang, H. (2017). "An Overview of Blockchain Technology: Architecture, Consensus, and Future Trends." In 2017 IEEE 6th International Congress on Big Data (pp. 557-564).

7. B. Jadhav, N. Maharnawar, R. Lakhotiya, R. Malpani, V. Ligde and P. Savale, "CryptoCertify: Certificate Validation and Authentication Using Blockchain Technology," 2024 1st International Conference on Cognitive, Green and Ubiquitous Computing (IC-CGU), Bhubaneswar, India, 2024, pp. 1-6, doi: 10.1109/IC-CGU58078.2024.10530809.

8. S. I. Mouno, T. Rahman, A. M. Raatul and N. a. Mansoor, "Blockchain-Enhanced Academic Certificate Verification: A Decentralized and Trustworthy Framework," 2024 International Conference on Advances in Computing, Communication, Electrical, and Smart Systems (iCACCESS), Dhaka, Bangladesh, 2024, pp. 1-5, doi: 10.1109/iCAC-CESS61735.2024.10499524.

9. S. Jha, A. Modak, R. Pise and S. Patil, "Certifier Dapp - Decentralized and Secured Certification System Using Blockchain," 2023 IEEE International Conference on Blockchain and Distributed Systems Security (ICBDS), New Raipur, India, 2023, pp. 1-6, doi: 10.1109/ICBDS58040.2023.10346509.

10. N. V. Chandgude, A. S. Salunke, C. Bawankar and V. Kumar, "Transparent and Tamper-Proof Certificate Verification on the Blockchain," 2023 4th International Conference on Computation, Automation and Knowledge Management (ICCAKM), Dubai, United Arab Emirates, 2023, pp. 1-6, doi: 10.1109/ICCAKM58659.2023.10449575.

11. T. Nargis, P. S. K, Prathyakshini, V. J, M. G. R and S. Salian, "A Secure Platform for Storing, Generating and Verifying Degree Certificates using Blockchain," 2023 7th International Conference on Trends in Electronics and Informatics (ICOEI), Tirunelveli, India, 2023, pp. 532-536, doi: 10.1109/ICOEI56765.2023.10125598.

12. T. Mangaiarkarasi, M. Prem, R. Madhavan, R. Vijaya Kumar, and J. Jaisurya, "Blockchain Based Certificate Validation," International Journal of Applied Engineering and Technology, vol. 9, pp. 156-160, 2020.

13. A. Chowdhary, S. Agrawal and B. Rudra, "Blockchain based Framework for Student Identity and Educational Certificate Verification," 2021 Second International Conference on Electronics and Sustainable Communication Systems (ICESC), Coimbatore, India, 2021, pp. 916- 921, doi: 10.1109/ICESC51422.2021.9532968.

14. Sumartono, Isnar and Siahaan, Andysah Putera Utama and Arpan, Arpan. (2016). Base64 Character Encoding and Decoding Modeling. International Journal of Recent Trends in Engineering and Research. vol. 2, pp. 63-68.

15. J. Anthal, S. Choudhary and R. Shettiyar, "Decentralizing File Sharing: The Potential of Blockchain and IPFS," 2023 International Conference on Advancement in Computation and Computer Technologies (InCACCT), Gharuan, India, 2023, pp. 773-777, doi: 10.1109/In-CACCT57535.2023.10141817.

16. M. Servais. "Networks," Ethereum.org, [Online]. Available: https://ethereum.org/en/developers/docs/networks/ [Accessed: 21- Aug-2024].

17. A. Banerjee. "What is the Rinkeby Faucet and Testnet?" BeIn-Crypto. [Online]. Available: https://beincrypto.com/learn/rinkeby-faucet- explained/. [Accessed: Aug. 21, 2024].

18. S. Walgenbach. "Ethereum Testnets: Navigating the Future of Blockchain Development," CoinPaper. [Online]. Available: https://coinpaper.com/3611/ethereum-testnets-navigating-the-future-of-blockchain-development. [Accessed: Aug. 21, 2024].

19. P. Gauravaram, "Security Analysis of salt password Hashes," 2012 International Conference on Advanced Computer Science Applications and Technologies (ACSAT), Kuala Lumpur, Malaysia, 2012, pp. 25-30, doi: 10.1109/ACSAT.2012.49.

20. G. Hatzivasilis, "Password-Hashing Status," Cryptography, vol. 1, no. 2, p. 10, 2017. doi: 10.3390/cryptography1020010.

Animal Detection using YOLO V8

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ABSTRACT

Animal detection is crucial in wildlife conservation, ecological studies, and agricultural management. Deep learning methods have recently shown significant potential in accurately and efficiently detecting animals from cameras, images, and videos. This paper presents a comprehensive approach to animal detection using the YOLO v8 framework and object detection algorithms. The proposed methodology includes data preprocessing, model training, and evaluation strategies specifically designed for animal detection. Various deep learning architectures, including CNNs and YOLO, are explored and analyzed for their applicability to this task. The experimental results demonstrate the effectiveness of the approach in achieving high accuracy and robustness in identifying and localizing animals in complex visual environments. This research advances animal detection technology, enhancing wildlife monitoring and conservation efforts, as well as improving agricultural ecosystem management. The study's findings highlight the success of the proposed models in achieving precise and reliable animal detection in diverse settings.

KEYWORDS: *CNN, YOLO, Deep learning, AI, Ultralytics.*

INTRODUCTION

The topic animal detection using Deep learning is an upcoming and highly emerging field around computer vision which grasp the power of artificial intelligence and to identify we will be using neural networks which is will be further used to classify various species of animals through Webcam, image and videos[4]. There are a vast number of practical applications which ranges from research in livestock management ,wildlife conservation, pet parenting care, and even for security systems. Convolutional neural networks (CNNs), which have been displaying amazing skills to discriminate and recognize animals based on their visual traits, attributes, etc., are the foundation of deep learning models.

A area of artificial intelligence (AI) and machine learning known as deep learning algorithms has transformed how complicated jobs are handled and approached throughout the years and attracted a lot of attention as a result.[7]

The main goal and focus of deep learning algorithm is to look after development and application of artificial neural networks, and categorically deep neural networks which further enable systems to learn and obtain a decision from data utilized, which resembles to human brain.

The models under deep learning are trained using a significant technique named as back propagtion. The tenure of training phase consists of providing labeled data to the model which makes future predictions[2]. In

between predictions and true labels the error occurred is calculated and directed backward through network connection which permits the model to adjust its weights and minimize the potential of error[9].b Traditional methods for animal detection, such as manual visual inspection or camera traps, are often time- consuming, labour-intensive, and limited in scalability. These methods can be subjective and struggle with accuracy, especially in complex environments or for small or camouflaged animals[5]. This research aims to address the limitations of the current system by:

1) Exploring various deep learning techniques tailored for Animal Detection

2) Enabling efficient Animal Detection within dynamic environment conditions

3) Develop a robust system that is capable of recognizing wide range of Animals

4) Fine-tuning and optimizing the trained models to improve their performance metrics such as accuracy, precision, recall, and computational speed.

5) Ensuring that the deployment of the animal detection system respects ethical guidelines and minimizes any potential harm or disruption to wildlife.

BACKGROUND & RELATED WORK

Traditional approaches to animal detection and animal re- identification heavily relied on manually engineered features. Nevertheless, recent strides in deep learning have brought substantial advancements in the performance of these tasks. In contemporary deep learning-based animal detection, convolutional neural networks (CNNs) are commonly employed to extract features from images or video frames[6]. These CNNs are trained on extensive datasets that encompass labeled images or videos containing animals. Once trained, these networks exhibit the ability to accurately identify animals in new images or videos.

Object detection involves locating and classifying objects within images or videos. Traditional methods relied on handcrafted features and classifiers, while deep learning- based approaches have largely replaced them due to their superior performance. Wildlife monitoring plays a crucial role in conservation efforts, biodiversity studies, and ecological research[4]. Traditional methods like camera traps or manual surveys are labor-intensive and time- consuming. Automating animal detection through deep learning can significantly enhance the efficiency and accuracy of wildlife monitoring.

Many researchers have employed camera trap data to create deep learning models for animal detection. This approach involves extensive data collection from camera traps set in natural habitats, capturing images of various animals. The development of well-annotated datasets tailored for animal detection is essential. Researchers compile datasets containing images of diverse species under different environmental conditions and camera setups.

Animal detection encompasses both localization, which identifies the animal's bounding box, and classification, which assigns a species label to the detected animal. Recent research emphasizes building algorithms that effectively localize and classify animals in images with varied backgrounds and occlusions.

Balancing sensitivity (detecting all animals) and specificity (minimizing false positives) remains a challenge. Researchers continually optimize models for accuracy, robustness, and scalability in conservation efforts.

METHODOLOGY

Yolo v8: The most recent and advanced YOLO model, YOLOv8, is useful for segmentation, object tracking, object recognition, and image classification applications. Ultralytics created YOLOv8, as well as the powerful and industry-defining YOLO v8 model. Many architectural and developer experience enhancements and modifications over YOLOv5 are included in YOLOv8.YOLOv8 is actively being developed, with Ultralytics working on new features and answering developer community comments.

Indeed, when Ultralytics releases a model, it enjoys long-term support: the organization works with the developer community around the world to make the deep learning

model the best it can be. YOLOv8 leverages an enhanced version of CSPDarknet53 a backbone architecture known for its efficiency in pinpointing object locations. This improved backbone is based on the CSPNet design, which offers a good balance between accuracy and speed by utilizing lightweight building blocks[1]. A critical aspect of object detection is extracting features at different scales. YOLOv8 addresses this through a novel feature fusion module. This module integrates features from various network layers, ensuring the model can effectively detect both large and small objects within an image. Real-world data presents a lot of variation. To make YOLOv8 robust, the developers implemented advanced data augmentation techniques. These techniques involve artificially modifying training data (like rotation, scaling, and color jittering) to improve the model's ability to handle unseen variations YOLOv8 splits a picture into its component parts and forecasts bounding boxes and class probabilities for every grid cell. It then uses a technique called non-maxima suppression to pick the most likely detections and filter out any overlaps[11]. YOLOv8 builds on this foundation to achieve state-of-the-art performance. It accomplishes this through several improvements, including: A more efficient backbone network based on Efficient Net for better high-level feature extraction.

- A new feature fusion module that combines information from various scales to improve detection for small objects. Enhanced data augmentation techniques to improve the model's ability to handle variations in real- world data.

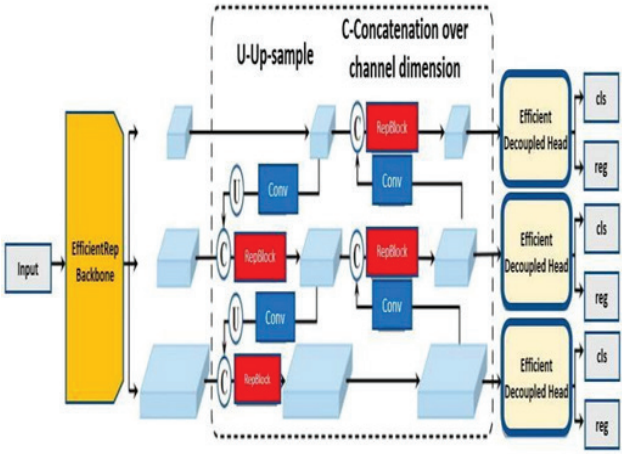
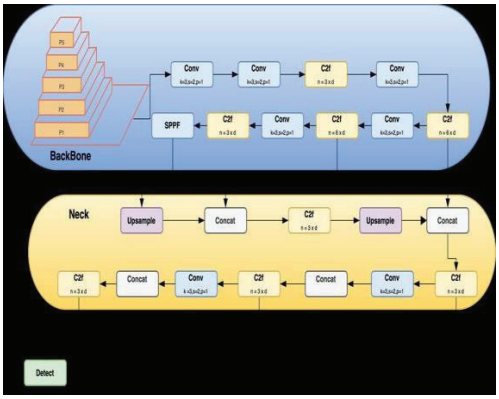


Fig. 1: Yolo V8 Working

PROPOSED ARCHITECTURE



Fis 2: Proposed Architecture working

WORKING

1. Data Collection: Data collection is most important part of our project, as Deep learning model requires huge amount of data for training. we have searched various Animal images dataset but we have found them not suitable for our project need. We have prepared custom dataset by collecting images from various sources including Google and other sources on internet. Upon downloading the photos, it was important to confirm that they were all of the intended animal and to eliminate any that had incorrect labels or were not useful.\
2. Training Images

Fig. 3 : Instructional Picture 1

Fig. 4: Instructional Picture 2

Fig. 5: Instructional Picture 3

3. Preprocessing: Images that are to be used for training deep learning model must be first trained, preprocessing ensures images are in consistent format to be used for training purpose. Deep learning model requires image preprocessing for ensuring that images get appropriately suitable and then fit into the model and important features must get preserved.

Training Set: The model learns patterns within the data to make predictions on unseen data. It is representative of the real-world data the model will encounter. The model is trained using this portion of the data. It must to be sizable enough to enable the model to discover patterns within the information.

Validation Set: During the training phase, this subset of data is used to adjust the hyperparameters and assess the model[7]. It prevents overfitting by offering a separate dataset for assessing the model's effectiveness.

Test Set: Offers a confident, impartial assessment of how well the model will generalize to actual data. After training and fine-tuning, the model's performance is evaluated using this subset of data. It should be completely separate from the training and validation sets and should represent the real-world data distribution. Data splitting: Popular real-time object detection software, YOLO (You Only Look Once), is renowned for its accuracy and speed. In the majority of machine learning tasks, including YOLO, data splitting often entails partitioning the dataset into training, validation, and testing sets.

Make sure that the data splitting process is done carefully to ensure that each set is representative of the entire dataset and that there is no data leakage between the sets.

Adjust the split sizes based on the size of your dataset and your specific requirements.

Model training: It is iterative process and involves many iterations leads to better accuracy. Training is the most important task in any Deep learning model. After data splitting into training, testing and validation data, training process starts by using training dataset. It is very time consuming process and requires very high computation power[9]. We have trained our model on Machine having Intel i5 processor, as Intel i5 processor is fast and reliable for training Deep learning dataset.

We have trained model using pretrained YOLOv8.pt. We perform 25 epochs for training model. At the end of training model file best.pt and last.pt get generated which is used for detection and classification.

PSEUDO CODE

Start

Import necessary libraries Import model file

Read Image. Video Open Webcam Add cv.waitKey()

Resize frame size=640

add image or video to model.predict()

- Divide the grid
- Predicted target bounding box
- Predict category of the target Confidence threshold:

If threshold > 0.55

Non-maximum suppression

Output the target bounding box annoting target type Else:

Give Up the Bounding Box

End

C = Pr(species) * IoU

IOU (Intersection of Union): Area of intersection/Area of union

Pr: Probability of species

K=n Mean Average Precision = 1/N Σ APk

K=1

FLOWCHART

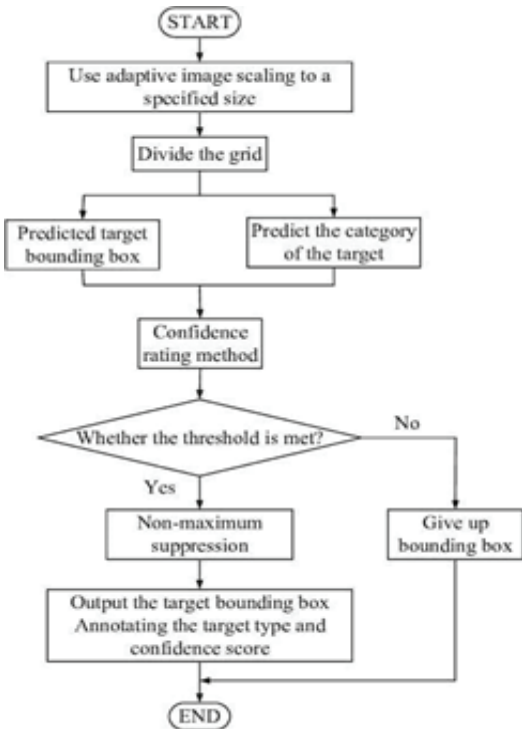


Fig 6: Flowchart

RESULT

The state-of-the-art (SOTA) model, YOLO v8, performed exceptionally well in this animal identification and categorization task. Similar to this, strong performance with F-measure metrics shows that these models can withstand data that is unbalanced. This further demonstrates the method's promise that it is reliable and extremely accurate in identifying images containing animals. The animal detection task achieved very high performance by using YOLO v8 framework for different types of animals with confidence ranging from 56.16% to 92.00 which is better than other YOLO object detection framework. Confidence threshold is one of the important checked while showing result.

Detected object and the name of animal is shown in the form of rectangular box with Confidence threshold.

These videos include all of the difficulties that arise in real time, such as occlusions, crowded backgrounds, and camera motions. We have examined the effectiveness of our system using a variety of quantitative metrics, including false recognition rate, reaction time, and recognition accuracy. The YOLO v8 model performs well after being trained from scratch, with classification accuracy ranging from 56.80% to 92.03%. For the majority of common animals, such as dogs, cows, hyenas, etc. model to support a wider range of animal species and complex environmental conditions. Additionally, investigating the integration of YOLO v8 with other advanced deep learning techniques could potentially enhance its capabilities and foster more accurate and comprehensive animal detection systems. Overall, the successful implementation of YOLO v8 in this project marks a significant step forward in the field of animal detection, offering promising prospects for the advancement of wildlife conservation, biodiversity monitoring, and sustainable ecosystem management.

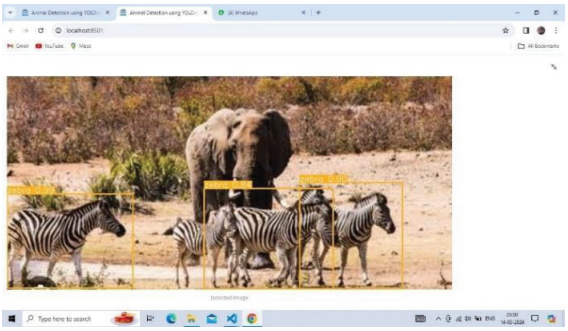


Fig 7: Results Image 1

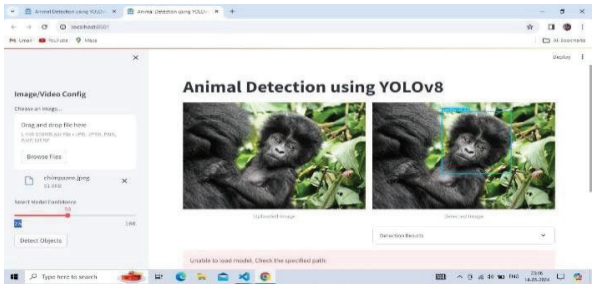


Fig 8: Results Image 2

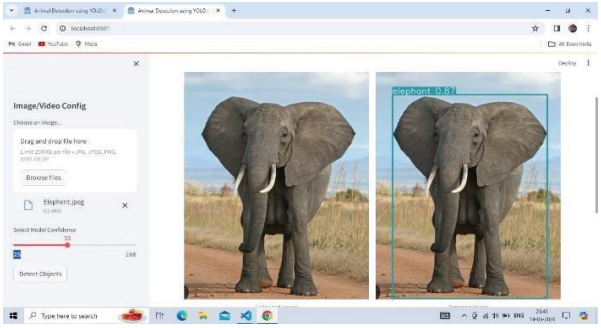


Fig 9 : Results Image

CONCLUSION

This project successfully demonstrated the effectiveness of YOLO v8 in the domain of animal detection. By leveraging the capabilities of this advanced deep learning model, we achieved significant strides in accurately identifying and localizing various animal species within diverse visual environments.

YOLO v8's remarkable speed and robustness enabled real-time detection, making it a practical solution for animal monitoring, ecological research, and conservation efforts. Through rigorous experimentation and fine- tuning, we optimized the model's parameters and hyperparameters, thereby enhancing its performance in detecting animals of varying sizes, scales, and orientations. In the future, more research should focus on growing the dataset and improving the design of the

FUTURE WORK

Deep learning has revolutionized animal detection, but there's still room for significant advancements. Conducting a more extensive evaluation on a larger and more diverse dataset encompassing various different types of animals, different geographical locations Will provide a more comprehensive understanding of the algorithm[6]. Detecting small animals or those partially occluded remains a challenge. Advancements in network architectures and training strategies specifically designed for small object detection will help in better object detection. Differentiating between closely related species or breeds based on subtle visual cues is an ongoing challenge. In real-world scenarios, some animal species might be rare in the data. Techniques like oversampling or cost-sensitive learning can be explored to improve detection accuracy for these under-represented classes. Exploring advanced techniques like data augmentation or domain adaptation could enhance the generalizing ability and robustness of these models by expanding their ability to handle unseen scenarios and improve their performance across diverse conditions. Deploying deep learning models on resource-constrained devices requires smaller and more efficient architectures to enable real- time animal detection in applications like drone-based conservation efforts.

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REFERENCES

1. "Animal detection and classification in image & video frames using YOLOV5 and YOLOV8," IEEE Conference Publication | IEEE Xplore, Nov. 22,2023.

   https://ieeexplore.ieee.org/document/1039475 0

2. "A Novel Approach To Detect and Track Small Animals using YOLOv8 and DeepSORT," Conference Publication | IEEE Xplore , Oct. 06, 2023. https://ieeexplore.ieee.org/document/1035

3. "Wild Animal Detection using Deep learning," S. K. L. and A. Edison, 2022 IEEE 19th India Council International Conference (INDICON), Kochi, India, pp. 1–5.

4. "Animal Detection in Man-made Environments," 2020 IEEE Winter Conference on Applications of Computer Vision (WACV), Snowmass, CO, USA, A. Singh, M. Pietrasik, G. Natha, N. Ghouaiel, K. Brizel, and N. Ray

5. Z. Zhang, Z. He, G. Cao and W. Cao, "Animal Detection From Highly Cluttered Natural Scenes Using Spatiotemporal Object Region Proposals and Patch Verification," in IEEE Transactions on Multimedia, vol. 18, no. 10, pp. 2079-2092, Oct. 2016

6. "Animal Detection Alert System," IEEE Conference Publication | IEEE Xplore, Nov. 09, 2022.

   https://ieeexplore.ieee.org/document/10040337

7. "Vision based technique for animal detection," IEEE Conference Publication | IEEE Xplore, Feb. 01, 2018. https://ieeexplore.ieee.org/document/8529660

8. "Wild Animal Detection using a Machine Learning Approach and Alerting using LoRa Communication," | IEEE Xplore , Dec. 23, 2022.

https://ieeexplore.ieee.org/document/10083577

9. "Enhancing Surveillance Systems with YOLO Algorithm for Real-Time Object Detection and Tracking, Dec. 11, 2023.

https://ieeexplore.ieee.org/document/10404710

10. "On-Board Real-Time pedestrian detection for micro unmanned aerial vehicles based on YOLO-V8," Jul. 25, 2023.

https://ieeexplore.ieee.org/document/10339502

11. https://www.researchgate.net/publication/371888779/figure/fig5/AS:11431281170734981@1687875457125/YOLOv8-architecture.ppm

Predictive Cyber Vigilance: Leveraging Machine Learning Algorithm for Effective Enforcement of IT Act

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ABSTRACT

Cybercrime generally is an offense, it's the one that we hear in our daily lives as technological advancement is grooming us daily in a big way. Cybercrime is any illegal and unauthenticated act that we specifically committed by using any electronic media like our cell phone, laptop, or computer network. We might mostly commit a crime if we are unaware of the legality of Cyber Security terminologies, which is a very sensitive term in terms of cybercrime. The increase in cyberattacks suggests the need for an automated model that is powered by artificial intelligence technologies that analyze and categorize cybercrime and recommend the relevant section of the IT Act. This study evaluates market needs, examines existing systems, and provides insight into India's cybercrime cells. These units preserve vast databases pertaining to cybercrimes, encompassing grievances and inquiries. In light of this, it is imperative to develop sophisticated models and automated systems driven by artificial intelligence in order to more precisely detect and classify these cybercrimes in accordance with the provisions of the Indian IT Act. This would speed up victim justice and improve the effectiveness of cyber cells.

KEYWORDS: *Cybercrime, Cyberspace, Machine Learning, Natural language processing, Cyber law, IT act, Indian IT act.*

INTRODUCTION

Technology globalization has resulted in an increase in cybercrimes, which is a serious threat to both personal safety and national security [1]. Cybercrime has become a ubiquitous concern in the constantly expanding digital ecosystem, resulting in financial losses, privacy breaches, and possible harm to persons and organizations. With the increase in smart cyber-attacks and the ever-expanding variety of illegal activities online, it has become critical to effectively combat cybercrime by leveraging the strength of modern technologies. 500 million cyberattacks worldwide were stopped in the first quarter of 2023 in India alone, out of a billion worldwide [1].

The integration of the Information Technology Act (IT Act) and Machine Learning-based cybercrime detection provides a powerful approach to defending against cybercriminals. The IT Act is an extensive regulation of law that allows authorities in India to handle cybercrime, provide justice to the victim, and protect cyberspace. Machine Learning (ML) algorithms, on the other hand, can analyze enormous amounts of information, find trends, and make intelligent predictions, making them perfect for identifying and mitigating cyber risks.

The combination of the IT Act with ML has several advantages. By exploiting the Act's legislative framework and implementing ML-powered detection methods, law enforcement agencies may proactively identify and respond to cyber events, providing a more secure digital environment for successful prosecutions.

This research investigates the feasibility of merging Machine Learning techniques with provisions from the IT Act to develop a viable cybercrime detection system. The research emphasized the important provisions of the Act that allow us to combat various cybercrimes, including breaches of data, identity theft, internet scams, as well as cyberstalking. Furthermore, we look at automating the identification and prevention of cybercrime, and a number of ML techniques, including anomaly detection, classification, and natural language processing, may be applied.

Fig 1. Total number of cybercrimes recorded in India between 2012 and 2022 [2]

The objective of this study is to highlight the significance of this amalgamation in strengthening cybersecurity efforts and fostering a safe digital environment. By shedding light on the synergies between the IT Act and ML, it aims to encourage policymakers, law enforcement agencies, and technology experts to collaborate and leverage this powerful alliance in the ongoing battle against cybercrime. As this study explore the potential of ML-powered cybercrime detection under the umbrella of the IT Act, it is expected to contribute to a comprehensive approach that harnesses technology to safeguard individuals, organizations, and the digital economy from the ever-evolving threats of the cyber realm.

Cybercrime

In the incredibly linked world of today, the quick rapid expansion of technologies has brought numerous benefits, but it has moreover spawned new and sophisticated types of criminal activities referred to as cybercrime. Cybercrime refers to any unlawful activity carried out using digital devices, networks, or the internet to cause harm, steal sensitive information, or disrupt critical infrastructures. This menace poses a significant challenge to individuals, businesses, and governments worldwide, as cybercriminals continue to exploit vulnerabilities and employ innovative tactics to achieve their malicious objectives. Thus, cybercrime can be understood as a broad term that includes computer-assisted crimes, such as using a computer to send harassing messages, in which computers and technology play a supporting role [3].

As the landscape of cybercrime becomes increasingly complex, it has become essential to develop robust and efficient methods to combat these illicit activities. One approach gaining momentum is the use of natural language data and ML algorithms for classification of cybercrime. This method capitalizes on the power of text representation to identify and categorize various types of cybercrimes, facilitating the implementation of suitable measures by security and law enforcement professionals.

This paper explores the significance of text-based classification in cybercrime detection and explore the most recent ML algorithms in this field. It examines the challenges associated with text data analysis, such as data privacy concerns and adversarial attacks, and discuss the potential benefits of employing this approach in real-world scenarios.

Cybercrime poses a significant threat to individuals and nations [4], causing financial losses and affecting military technology. It affects millions of people and includes traditional criminal offenses like drug trafficking and terrorism. Law enforcement is working to develop advanced technologies to combat cybercrime, such as data mining, machine learning, and bioprinting [5]. To prevent harm, people must be alert and informed of the many kinds of cybercrimes. It takes an intelligent attitude to resist these actions.

Cyberspace

The virtual environment that permeates every aspect of our globally networked world, known as cyberspace,

crosses national borders to expand into a massive, dynamic web of digital exchanges. It includes all the internet, including webpages, social networking sites, online databases, and the many digital environments where transactions and information exchange take place. People, companies, and governments manage a complicated web of information, communication, and services in this intangible world. But the vastness of cyberspace also brings with it difficulties, from privacy issues and cybersecurity risks to digital governance problems and moral dilemmas. The idea of cyberspace is still at the center of international debates as technology develops, influencing how people interact, work together, and face the benefits and dangers that come with living in the digital age. Traditional physical, social, and cognitive spaces have an impact on cyberspace, and the digital world [6].

Need of Cyber Law

The necessity of cyber law is becoming more and more apparent as the digital world develops and grows. Technology-based economies are particularly concerned about cybersecurity, which makes secure and sustainable online ecosystems necessary [7]. The speedy growth rise of technology and the pervasive adoption of the internet have brought numerous benefits to society, but they have also led to a surge in cybercrime. Cybercriminals exploit digital platforms to carry out a wide range of illegal activities and behaviors like hacking, data breaches, identity fraud, internet fraud, and cyberbullying. To counter these threats effectively and to facilitate the victims of cybercrime, there is an urgent need for a comprehensive legal framework that addresses cybercrime in a systematic and enforceable manner. This is where cyber law plays a crucial role.

Fig. 2. Need of IT Act

In the digital era, the IT Act is essential because it provides a set of rules for controlling the use, access, and security of digital information. It offers recommendations for safeguarding against online fraud, identity theft, hacking, and data breaches. The IT Act guarantees the legal validity of electronic contracts and documents while fostering safe communication and the expansion of e-commerce. Dealing with cybercrime, digital privacy, and trade promotes economic progress, innovation, trust, and the general well-being of society.

REVIEW OF THE LITERATURE

The research suggests a multifaceted method for approaching, understanding, and preventing cybercrime, including the study of cyber threats, using ML for identification, and improving law enforcement strategies. It will analyze the historical context of cybercrime, identify patterns and trends, and analyze literature. This study focuses on proactive cybercrime identification and categorization using ML. The research aims to create robust models that identify small irregularities and patterns indicative of cyber threats using various methods and datasets.

Rise in Cyber Crime

Because of the increasing complexity of cybercriminals and the expansion of internet connectivity, cybercrime is a growing threat. Anonymity, exponential expansion in digital data, and insufficient cybersecurity safeguards are some of the factors that make people and businesses vulnerable.

Geetika Bhardwaj et al [13] presented in their study that According to the National Commission for Women, there was a 46% increase in crimes against women at the start of 2021 compared to 2020. This urgent problem must be resolved, and the first step in taking proactive actions to lower the incidence of crime against women in the future is to gather crime data to assess and comprehend the crime rate and forecast future trends based on available data.

Olena V. et al [14] presented that Globally, there is a rise in cyberattacks, especially in industries like finance, retail, technology, and communication that includes substantial financial turnover. Because of its vast region and lack of effective coordination, combating

cybercrime is difficult.

Gangwar Suraj et al [15] said that the Internet of Things, cloud services, and improved connections have all contributed to an upsurge in cybercrime instances in recent years. Cybercriminals may even threaten human lives as they target industrial control systems, elections, and digital wildfires. Cybercrimes are expected to rank among the top five worldwide threats according to the "Global Risks 2018" study.

Shuai Chenet al [16] found in their study that Globally, there is a positive correlation between cybercrime and social, economic, and technological variables; most cybercrimes occur in urbanized areas with greater infrastructure. There is a negative correlation between cybercrime and cybersecurity and political issues.

P Datta et al [17] In their study show an increase in fraud cases, primarily affecting 20-29-year-olds, particularly mothers and children, necessitating awareness campaigns to combat cybercrime in India.

Chudasama Dhaval et al [18] suggested in their study that attackers frequently utilize third-party apps to send money, which results in fraud. Takeovers by the government might lower crime and promote transparency by maintaining records and tracking transactions. As per the report of NCRB 2022 following are the motives of cybercrime committed in India during the year 2022.

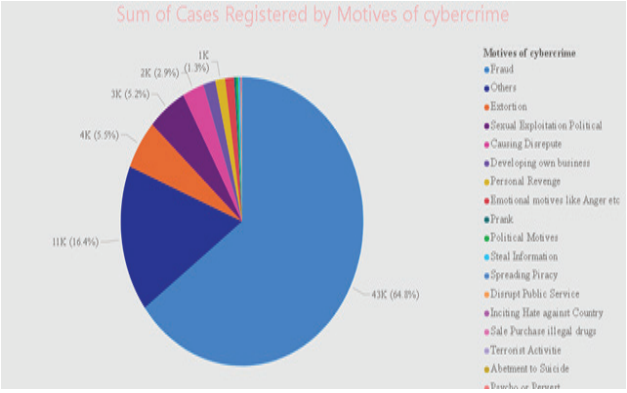

Fig. 4. Motives of cybercrime in India 2022 [19]

Identification of Cybercrime

Text-based cybercrime detection analyses textual data to find possible risks using cutting-edge technology like models for machine learning and methods for natural language processing (NLP). On examining language clues, writing styles, and well-known terms, we can identify dangerous material, malware-laden emails, and phishing efforts. This tool is essential for all-encompassing cybersecurity plans and is anticipated to change as technology progresses. To date, several text-based cybercrime algorithms have been identified.

Text based cybercrime detection methods

To date following text-based cybercrime detection methods have been identified.

Table 2. Text-Based Cybercrime Detection Methods

Author Name/ Reference Number/ Year of Publication	Type of Crime Detected	Type of Machine Learning	data source	Results	Future Scope
Rupa Ch et all /16 May 2020 [20]	Copyright, Hacking, Identify theft Classification	k-means clustering algorithm, TFIDF vector technique	Kaggle and CERT-In	According to statistics classified with 99%, the state of Madhya Pradesh has a higher crime rate than Haryana.	To give the criminal authorities some tailored actions and countermeasures to help slow the rise of cybercrimes that happen often in that particular area.
AK Ghazi et all /16 Feb 2021 [21]	Phishing and its types	Routine Activity Theory. Technological proficiency differential	Information is gathered through interviews with academic scholars, security experts, and hackers.	Theory of Routine Activities , with some modifications, is useful for phishing and cyber-crime analysis (S 48.3%, N = 30)	Further research is required to determine the effectiveness of testing and training.

V. Mahor et all / September 2021 [22]	Cyber Crime Activity detected for Online social networking	sigmoid kernel, support vector machine (SVM)	Government site for Cybercrime	97.12 Percent	More Data set should be taken for improved results.
Farkhund Iqbal / 09 January 2019 [23]	find and extract pertinent forensic data from sizable, dubious chat logs	WordNet-based criminal information mining	Social networking chat logs, Reuters-21578 [41] dataset	Ten to twenty percent more precise clusters and their subjects	Findings might be cross-referenced with crime ontologies to see suspect Involvement
Shiza Andleeb / 13 February 2020 [24]	bullying text	Support Vector Machine classifier	myspace.com and Perverted-Justice.com	87.14% of classification accuracy	
Markus Bertl / 2019 [25]	Risks in the field of digital healthcare.	extraction, semantic fields, statistical calculations	The Austrian Armed Forces' National Defence Academy (Doc Center /NDA), GDELT	Digital health technologies are not exempt from cyber risks, and cyberattacks pose an increasing risk to individuals, governments, and organizations.	The study underscores the challenges posed by datasets lacking structured metadata
A.Almansoori et al / May 2021 [26]	Research Question	Python programming	Social media Cyber Crime Data set	e ages between 20 and 25 commit more crimes.	AI techniques can be incorporated.
Jisu Kim / 2021 Jul 28 [27]	Fake news	Clustering algorithm (Latent Dirichlet Allocation)	T/F news dataset	T/F claims 80% COVID fake news.	Training features can be incorporated for future knowledge-based detection models.

Law and enforcement to combat cybercrime

Hemakshi Pandey et al, [39] offer a solid method for leveraging ensemble learning techniques to classify cybercrime under sections 66 and 67 of the IT Act 2000. Performance is improved by 96.55% by the model stacking of SVM, Logistic Regression, Decision Tree, and Random Forest. The methodology employs the Bag of Words approach for feature engineering. Since the goal of this research is to improve model performance and resilience, cyber-crime cells in India will benefit from it.

Shefali Batra et al [40] talk about cybercrime, different kinds of cyber criminals, how cybercrime affects the globe, and how to avoid it. Additionally, statistical data on the various forms of cybercrime and its increase over the past several years will be analyzed in this article.

Prerna Kapoor et al [41] described that regression and correlation are used to examine the crime patterns according to the states where crimes are more likely to occur as well as the relationships between such states. Regression and correlation analysis are used in a criminal pattern investigation based on the IT Act 2000. The act of posting someone else's private photographs is positively correlated with obtaining a stolen computer.

Shivani Verma et al [42] discussed the applicability of cyber laws that prohibit crimes committed, various numbers of threats, and attacks of the cyber found which can be a major problem in cyberspace.

Swati Kumari et al [43] reported a study, which used the Face Pager software application to process data that was acquired from Twitter and Facebook. The objective is to extract the cybercrime data, segregate it into two labeled classes (i.e., positive and negative), and preprocess it to get a clean training dataset (Sentiment Analysis) using supervised machine learning.

Rupa Ch et al [20] analyzed cybercrime rates at the state level in India, the research offers a computational tool that uses machine learning. This tool uses security

analytics and data analytic methodologies to identify offenses with 99 percent accuracy.

Rani Supriya et al [44] emphasize in their study that dynamic cybercrime is on the rise due to the 'Digital India Movement'; thus, the existing cyber legal framework must be modified to stop these kinds of crimes. As per the report of NCRB following are the cybercrimes reported under the category of the Indian IT Act in year 20222.

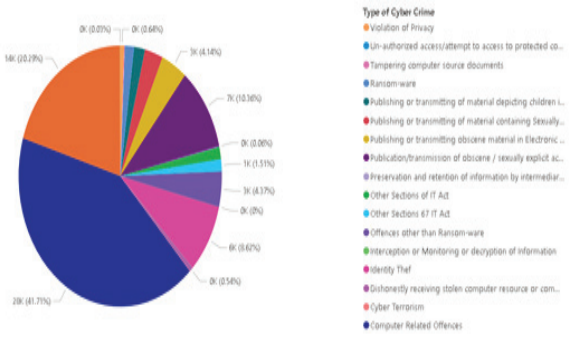

Fig. 5. Types of cybercrime registered during year 2022 under Indian IT Act [19]

STATE OF THE ART: COUNTERMEASURE TECHNIQUES FOR CYBER CRIME

Without a doubt, it is critical that both people and organizations take proactive steps to safeguard themselves given the rising incidence of cybercrime. The following recommendations are meant to assist in combating cybercrime.

Security Awareness Training: Educate individuals within organizations and the public about best practices in cybersecurity. This entails being aware of phishing efforts, creating secure passwords, and comprehending the possible dangers associated with certain online behaviors.

Robust Authentication: To provide an additional degree of protection over and beyond passwords, use multi-factor authentication (MFA). This makes it more difficult for unauthorized individuals to access accounts and systems.

Patching and regular software updates: Keep all software, including systems software, antivirus programs, and applications, current with the most recent security updates. Many cyber-attacks exploit vulnerabilities in outdated software.

Intrusion Prevention Systems and Firewall: Employ firewalls and systems that prevent intrusions to monitor and control network traffic, identifying and blocking potentially malicious activity.

Data Encryption: Use encryption to protect sensitive information during transmission and storage. This helps safeguard data even if unauthorized access occurs.

Regular Backups: Conduct regular backups of critical data and systems. In the event of a cyber-attack, having up-to-date backups can facilitate recovery without succumbing to ransomware demands.

Plan for Responding to Incidents: Create and put into action a thorough incident response strategy to promptly detect, respond to, and recover from cybersecurity incidents. This plan should involve all relevant stakeholders within an organization.

Network Segmentation: Segmenting networks helps contain the spread of cyber threats. If an attacker gains access to one part of the network, segmentation makes it more challenging for them to move laterally.

Collaboration and Information Sharing: Foster collaboration and information sharing within the cybersecurity community, as well as between the public and private sectors. This collective intelligence can help anticipate and respond to emerging threats more effectively.

Employee Vetting and Monitoring: Conduct extensive background checks on their staff and limit access to private information based on job roles. Monitor user activities to detect any unusual behaviors that may indicate a security threat.

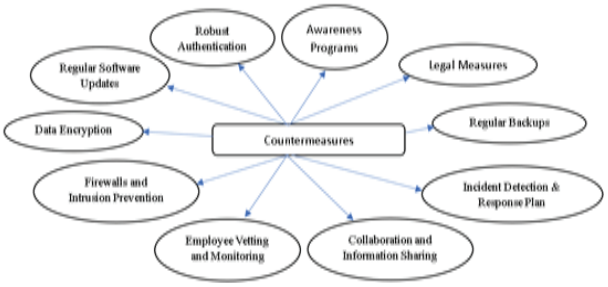

Fig. 6: Countermeasure of Cybercrime

PROPOSED FRAMEWORK: MACHINE LEARNING FOR PRACTICING LAW

Recent research has shown that ML techniques are increasingly needed to determine which IT Act applies to cybercrimes that have been committed. While previous research has concentrated on categorizing cybercrime, it has not addressed the critical component of delivering victim justice by identifying the relevant IT Act. This makes it easier to conduct investigations more quickly and increases the likelihood that victims of cybercrimes will receive justice. Furthermore, machine learning helps law enforcement to remain current with changing legal requirements and cyber threats, allowing for proactive enforcement actions to successfully combat cybercrime.

Fig. 7: Proposed Model for practicing Cyberlaw

The proposed model aimed at identifying the applicable IT Act for committed cybercrimes, the process begins with data collection from diverse sources including news articles, social media data, government websites, and private organizations. This comprehensive dataset serves as the foundation for training the ML model. Subsequently, the collected data undergoes pre-processing steps such as tokenization and lemmatization to standardize and clean the text data. Following this, feature extraction techniques such as bag of words and n-grams are applied to identify key features and patterns in the text data that are indicative of different cybercrimes and relevant legal statutes. Once the data is pre-processed and features are extracted, the dataset is split up into three categories, 75% to train the dataset, 20% for testing, and the remaining 5% for validation purposes. This division ensures that the model is trained on most of the data, while also having sufficient data for testing and validation to evaluate its performance and generalization ability.

Following training the machine learning model for the training data, a classification summary is generated to evaluate the performance of the model in predicting the applicable IT Act for various cybercrime scenarios. Finally, the model is tested on the unseen testing data to validate its effectiveness in accurately identifying the relevant legal framework for addressing cybercrimes. By following this methodology, the proposed model aims to provide law enforcement agencies with a reliable tool for automating the process of identifying the applicable IT Act for different types of cybercrimes, thereby facilitating more efficient and effective legal interventions in cybercrime cases.

CONCLUSION

In conclusion, a revolutionary strategy that combines cutting-edge ML technologies with current systems is needed to combat the changing nature of cybercrime in India. Our ability to classify cybercrimes accurately in accordance with the Indian IT Act can be greatly improved by creating automated tools and complex models. Consequently, victims will receive justice more quickly and effectively. The suggested modifications not only meet the demands of the market today, but they also establish a standard for future breakthroughs in cybercrime management.

REFERENCES

1. Ians, "500 mn cyberattacks blocked in India in Q1 2023, attacks grew 29% globally," New Delhi, May 10, 2023.
2. Tanushree Basuroy, "Number of cyber crimes reported in India 2012-2022," Dec. 2023.
3. A. Okutan and Y. Çebi, "A Framework for Cyber Crime Investigation," Procedia Comput Sci, vol. 158, pp. 287–294, 2019, doi: 10.1016/j.procs.2019.09.054.

4. S. Kharat, "Cyber Crime A Threat to Persons, Property, Government and Societies," SSRN Electronic Journal, 2017, doi: 10.2139/ssrn.2913438.

5. A. M. Bossler and T. Berenblum, "Introduction: new directions in cybercrime research," J Crime Justice, vol. 42, no. 5, pp. 495–499, Oct. 2019, doi: 10.1080/0735648X.2019.1692426.

6. H. Ning, X. Ye, M. A. Bouras, D. Wei, and M. Daneshmand, "General Cyberspace: Cyberspace and Cyber-Enabled Spaces," IEEE Internet Things J, vol. 5, no. 3, pp. 1843–1856, Jun. 2018, doi: 10.1109/JIOT.2018.2815535.

7. S. Sadik, M. Ahmed, L. F. Sikos, and A. K. M. N. Islam, "Toward a Sustainable Cybersecurity Ecosystem," Computers, vol. 9, no. 3, p. 74, Sep. 2020, doi: 10.3390/computers9030074.

13. Geetika Bhardwaj and R. K. Bawa, "Performance of Machine Learning Models on Crime Data," in Proceedings of Fourth International Conference on Computing, Communications, and Cyber-Security, 2023.

14. O. V. Sviatun, O. V. Goncharuk, C. Roman, O. Kuzmenko, and I. V. Kozych, "Combating Cybercrime: Economic and Legal Aspects," WSEAS TRANSACTIONS ON BUSINESS AND ECONOMICS, vol. 18, pp. 751–762, Apr. 2021, doi: 10.37394/23207.2021.18.72.

15. S. Gangwar and V. Narang, "A Survey on Emerging Cyber Crimes and Their Impact Worldwide," in Research Anthology on Combating Cyber-Aggression and Online Negativity, IGI Global, 2022, pp. 1583–1595. doi: 10.4018/978-1-6684-5594-4.ch080.

16. S. Chen et al., "Exploring the global geography of cybercrime and its driving forces," Humanit Soc Sci Commun, vol. 10, no. 1, p. 71, Feb. 2023, doi: 10.1057/s41599-023-01560-x.

17. P. Datta, S. N. Panda, S. Tanwar, and R. K. Kaushal, "A Technical Review Report on Cyber Crimes in India," in 2020 International Conference on Emerging Smart Computing and Informatics (ESCI), IEEE, Mar. 2020, pp. 269–275. doi: 10.1109/ESCI48226.2020.9167567.

18. Dhaval Chudasama, Darsh Rajeshkumar Patel, Abhishek Shah, and Nihal Shaikh, "Research on Cybercrime and its Policing," American Journal of Computer Science and Engineering Survey, vol. 8, Nov. 2020.

19. National Crime Records Bureau, "Crime in India 2021: Vol III," New Delhi, Aug. 2022.

20. R. Ch, T. R. Gadekallu, M. H. Abidi, and A. Al-Ahmari, "Computational System to Classify Cyber Crime Offenses using Machine Learning," Sustainability, vol. 12, no. 10, p. 4087, May 2020, doi: 10.3390/su12104087.

21. A. K. Ghazi-Tehrani and H. N. Pontell, "Phishing Evolves: Analyzing the Enduring Cybercrime," Vict Offender, vol. 16, no. 3, pp. 316–342, Apr. 2021, doi: 10.1080/15564886.2020.1829224.

22. V. Mahor, R. Rawat, S. Telang, B. Garg, D. Mukhopadhyay, and P. Palimkar, "Machine Learning based Detection of Cyber Crime Hub Analysis using Twitter Data," in 2021 IEEE 4th International Conference on Computing, Power and Communication Technologies (GUCON), IEEE, Sep. 2021, pp. 1–5. doi: 10.1109/GUCON50781.2021.9573736.

23. U. V. Navalgund and P. K., "Crime Intention Detection System Using Deep Learning," in 2018 International Conference on Circuits and Systems in Digital Enterprise Technology (ICCSDET), IEEE, Dec. 2018, pp. 1–6. doi: 10.1109/ICCSDET.2018.8821168.

24. S. Andleeb, R. Ahmed, Z. Ahmed, and M. Kanwal, "Identification and Classification of Cybercrimes using Text Mining Technique," in 2019 International Conference on Frontiers of Information Technology (FIT), IEEE, Dec. 2019, pp. 227–2275. doi: 10.1109/FIT47737.2019.00050.

25. Markus Bertl, "News analysis for the detection of cyber security issues in digital healthcare A text mining approach to uncover actors, attack methods and technologies for cyber defense," Young Information Scientist, vol. 4, Oct. 2019.

26. A. Almansoori, M. Alshamsi, S. Abdallah, and S. A. Salloum, "Analysis of Cybercrime on Social Media Platforms and Its Challenges," 2021, pp. 615–625. doi: 10.1007/978-3-030-76346-6_54.

27. J. Kim, J. Aum, S. Lee, Y. Jang, E. Park, and D. Choi, "FibVID: Comprehensive fake news diffusion dataset during the COVID-19 period," Telematics and Informatics, vol. 64, p. 101688, Nov. 2021, doi: 10.1016/j.tele.2021.101688.

28. Nadeem Ali Muhammad and Rida Fatima, "Role of image processing in digital forensics and cybercrime

detection," International Journal of Computational And Innovative Sciences, vol. 1, Mar. 2022.

29. M. F. Bin Ahmed, M. S. U. Miah, A. Bhowmik, and J. B. Sulaiman, "Awareness to Deepfake: A resistance mechanism to Deepfake," in 2021 International Congress of Advanced Technology and Engineering (ICOTEN), IEEE, Jul. 2021, pp. 1–5. doi: 10.1109/ICOTEN52080.2021.9493549.

30. B. Zou, M. Nurudeen, C. Zhu, Z. Zhang, R. Zhao, and L. Wang, "A Neuro-Fuzzy Crime Prediction Model Based on Video Analysis," Chinese Journal of Electronics, vol. 27, no. 5, pp. 968–975, Sep. 2018, doi: 10.1049/cje.2018.02.019.

31. C. V. Amrutha, C. Jyotsna, and J. Amudha, "Deep Learning Approach for Suspicious Activity Detection from Surveillance Video," in 2020 2nd International Conference on Innovative Mechanisms for Industry Applications (ICIMIA), IEEE, Mar. 2020, pp. 335–339. doi: 10.1109/ICIMIA48430.2020.9074920.

32. P. Chitrakar, C. Zhang, G. Warner, and X. Liao, "Social Media Image Retrieval Using Distilled Convolutional Neural Network for Suspicious e-Crime and Terrorist Account Detection," in 2016 IEEE International Symposium on Multimedia (ISM), IEEE, Dec. 2016, pp. 493–498. doi: 10.1109/ISM.2016.0110.

33. L. Li, P. L. Correia, and A. Hadid, "Face recognition under spoofing attacks: countermeasures and research directions," IET Biom, vol. 7, no. 1, pp. 3–14, Jan. 2018, doi: 10.1049/iet-bmt.2017.0089.

34. P. Vitorino, S. Avila, M. Perez, and A. Rocha, "Leveraging deep neural networks to fight child pornography in the age of social media," J Vis Commun Image Represent, vol. 50, pp. 303–313, Jan. 2018, doi: 10.1016/j.jvcir.2017.12.005.

35. P. A. Barraclough, G. Fehringer, and J. Woodward, "Intelligent cyber-phishing detection for online," Comput Secur, vol. 104, p. 102123, May 2021, doi: 10.1016/j.cose.2020.102123.

36. A. Cohen, N. Nissim, and Y. Elovici, "MalJPEG: Machine Learning Based Solution for the Detection of Malicious JPEG Images," IEEE Access, vol. 8, pp. 19997–20011, 2020, doi: 10.1109/ACCESS.2020.2969022.

37. J. Yang, S. Xiao, A. Li, G. Lan, and H. Wang, "Detecting fake images by identifying potential texture difference," Future Generation Computer Systems, vol. 125, pp. 127–135, Dec. 2021, doi: 10.1016/j.future.2021.06.043.

38. D. Vasan, M. Alazab, S. Wassan, H. Naeem, B. Safaei, and Q. Zheng, "IMCFN: Image-based malware classification using fine-tuned convolutional neural network architecture," Computer Networks, vol. 171, p. 107138, Apr. 2020, doi: 10.1016/j.comnet.2020.107138.

39. H. Pandey, R. Goyal, D. Virmani, and C. Gupta, "Ensem_SLDR: Classification of Cybercrime using Ensemble Learning Technique," International Journal of Computer Network and Information Security, vol. 14, no. 1, pp. 81–90, Feb. 2021, doi: 10.5815/ijcnis.2022.01.07.

40. S. Batra, M. Gupta, J. Singh, D. Srivastava, and I. Aggarwal, "An Empirical Study of Cybercrime and Its Preventions," in 2020 Sixth International Conference on Parallel, Distributed and Grid Computing (PDGC), IEEE, Nov. 2020, pp. 42–46. doi: 10.1109/PDGC50313.2020.9315785.

41. P. Kapoor, P. K. Singh, and A. K. Cherukuri, "IT Act Crime Pattern Analysis using Regression and Correlation Matrix," in 2020 8th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions) (ICRITO), IEEE, Jun. 2020, pp. 1102–1106. doi: 10.1109/ICRITO48877.2020.9197835.

42. Shivani Verma, Siddharth Nayak, and Deepak Kumar Deshmukh, "A Survey of Emerging Cyber Crimes and Their Probable Solutions," Research Journal of Engineering and Technology, vol. 11, no. 2, 2020.

43. S. Kumari, Z. Saquib, and S. Pawar, "Machine Learning Approach for Text Classification in Cybercrime," in 2018 Fourth International Conference on Computing Communication Control and Automation (ICCUBEA), IEEE, Aug. 2018, pp. 1–6. doi: 10.1109/ICCUBEA.2018.8697442.

44. Rani Supriya, Km. Pranjali Tomar, Kuljit Singh, Mr. Manish Bhardwaj, and Mr. Shashank Tyagi, "CYBER CRIMES IN INDIA: A CRITICAL ANALYSIS," International Journal of Mechanical Engineering, vol. 7, Jun. 2022.

Optimizing Business Productivity: A Deep Learning Approach Using OAtt-RNN and Botox Optimization Algorithm

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ABSTRACT

The management by goals acts as a primary component of action for analyzing the performance of the organization's demand of the employees in any bound of organization territory. The intelligence of the organization supports collecting significant data from a huge variety of unstructured data and changes them into useful data that enables the organizations to make illuminated policy decisions and enhance the organization's productivity and efficiency. The complexities facing any enterprise in decision-making and business intelligence include risk-taking capability, resource failure, poor preparation, and plan failure. Deep learning has not attained much attention due to the efficacy has not been clearly examined in the decision-making within the organization. Hence in this proposed model, an efficient deep learning-aided system is developed for making decisions to improve production growth, where the data needed for the analysis is gathered from different business sectors. The collected data is applied to the Optimized and Attention Recurrent Neural Network (OAtt-RNN) for providing suggestions, which helps to boost up the productivity of the business. The decision-making efficiency of the proposed model is boosted by fine tuning the attributes from OAtt-RNN using Botox Optimization Algorithm (BOA). Effective business management generates a positive work environment and motivates employees to concentrate more on their work. The obtained outcome of the designed system is contrasted with other conventional models using different performance metrics to ensure the efficiency of our model.

KEYWORDS: *Business organizations, Performance management, Productivity enhancement, Optimized and attention recurrent neural network, Botox optimization algorithm.*

INTRODUCTION

The widespread and continuous integration of internet technologies within organizations has significantly impacted overall performance, intensifying market competition and making market predictions increasingly complex. In today's environment, organizations can no longer afford to pursue growth without strategic planning.[1] To ensure sustained progress, it is essential for businesses to prioritize organizational health, focusing on the capabilities of internal employees and the quality of internal performance management, rather than merely on organizational size.[2]. In the digital era, organizations are increasingly incorporating internet technologies into their performance management strategies to support holistic organizational growth. This shift places a greater emphasis on the development and assessment of employees' comprehensive abilities and personal skills. Advanced validation tools are being employed to facilitate thorough evaluation processes, encompassing data entry accuracy, associated statistics, and computer-based validations.[3]Moreover, by leveraging internet technologies to enhance employee performance management and overcome traditional appraisal limitations, organizations can effectively link performance outcomes to salary and promotion decisions.[4] This approach not only strengthens staff management but also fosters a cohesive and motivated work environment, reduces internal conflicts, and enhances organizational unity.

In traditional organizational management, much of the workflow is carried out manually, which is often inefficient and detrimental to overall organizational productivity.[5] This manual approach significantly reduces management efficiency, leading to wasted human resources. Additionally, physical management processes require substantial financial investment, which quickly escalates organizational expenses. [6] The reliance on manual handling also increases the likelihood of administrative errors due to varying personnel quality and other factors, creating unnecessary complications for the organization. In the modern internet era, organizations increasingly rely on office software as an essential part of their management strategies to conduct performance management[7]. Despite this shift, many organizations still adhere to outdated management practices and concepts, failing to embrace more advanced and effective management experiences and tools[8]. This reluctance to evolve hampers their ability to fully optimize performance and efficiency. Failure to invest in cutting-edge technology makes it difficult for organizations to access market data promptly and accurately, leading to challenges in strategic implementation [9]. Traditional research has highlighted the influence of a strong organizational culture on enhancing technological performance, but the specific mechanisms behind this relationship remain underexplored. Numerous studies have demonstrated that an organization's culture significantly impacts its technological capabilities[10]. However, despite extensive research in this area, the integration of deep learning innovations with technological performance and organizational culture is still insufficiently explored. The key contributions of the proposed performance management strategy in business organizations are as follows:

1. Introducing a novel performance management approach that leverages adaptive deep learning to enhance organizational productivity.
2. Developing the OAtt-RNN technique, which combines Recurrent Neural Networks (RNN) with an attention mechanism and adaptive elements to provide more effective recommendations for improving performance management within a business setting. The Botox Optimization Algorithm (BOA) is proposed for fine-tuning the attributes of the OAtt-RNN.
3. Recommending the BOA to support performance enhancement and parameter optimization in the OAtt-RNN technique, thereby reducing error rates in the implemented model.
4. Evaluating the effectiveness of the proposed performance management strategy in comparison to traditional models used in business organizations.

LITERATURE SURVEY

Related Works

In 2024, Guo [11] explored the significant relationship between the performance of high-tech organizations, open technology innovation, and innovation culture through the application of deep learning techniques. The study revealed a strong correlation between technological innovation and corporate culture performance, and the incorporation of deep learning notably enhanced the reliability and accuracy of the findings.

In 2023, Olkiewicz et al. [12] focused on quality management within organizations. The study aimed to identify and validate the effectiveness of quality management tools using regression analysis. The results confirmed that these management models significantly increased the likelihood of effective quality management.

In 2022, Romero et al. [13] proposed a model for assessing process capability using original text input through smart devices, reducing the need for human intervention while delivering reliable results. This work combined Long Short Term Memory (LSTM) networks with ontology-based rules to evaluate operational attribute ratings.

In 2024, Wu and Qin [14] utilized decision-making and machine learning techniques to validate smart organizational control and network management. The study employed a multi-agent probabilistic reinforcement approach to manage control, resource allocation, and business processes, and evaluated these strategies against various performance metrics.

In 2023, Dun et al. [15] developed and evaluated processGAN, an organizational process enhancement mechanism based on Generative Adversarial Networks (GAN). This tool was designed to generate innovative ideas for organizational improvement. The findings demonstrated that processGAN boosted the creativity of process developers and effectively translated these ideas into practical applications.

Research Gaps and Challenges

Performance management is a component that supports the managers evaluate and observe the performance of the employees to confirm that the employees are performing towards the goals of the organization. It can support the organization enhance productivity and efficiency and generate a performance-driven territory, where all members of the team are aligned concerning progress, accountability, direction, and priorities. Analyzing the performance management in business organizations is very significant and numerous conventional works performed this. However, the traditional models have some limitations, which are listed as follows. Also, Table I gives some existing performance management model's merits and limitations.

Analyzing performance management within business organizations is essential, and many conventional studies have addressed this topic. However, traditional models have certain limitations, which are outlined below. Table I summarizes the merits and limitations of existing performance management models. Despite the importance of performance management for enhancing productivity, there has been limited research in recent years, highlighting the need for a new, effective strategy. Traditional approaches often rely on machine learning, requiring manual intervention and higher computational demands. This indicates a need for a deep learning-based automated performance management system. Existing systems fall short in meeting organizational goals, such as improved productivity and customer satisfaction, necessitating a new approach. While some studies have applied deep learning models, they often lack parameter tuning, which lowers accuracy. Therefore, optimizing parameters for deep learning is essential to enhance the performance management system's effectiveness.

Hence, a new performance management mechanism in business organizations is presented with the help of deep learning to overcome these challenges and improve outcomes.

Table 1. Features and Challenges of Conventional Performance Management Strategies in Business Organizations

Author [citation]	Methodology	Features	Challenges
Guo [11]	Fuzzy set theory	It provides a flexible system for designing. It helps to design complex decision making tasks.	It utilizes more time for computation. Its accuracy is reduced when processing the imprecise data.
Olkiewicz et al. [12]	Logistic regression	It is relatively simple to develop and interpret. It is very effective to train and test.	It needs a huge sample size. It is susceptible to overfitting.
Romero et al. [13]	LSTM	It effectively handles long term dependencies. It can model complex sequential data.	It is a highly complicated model. It needs more data for the training process.
Wu and Qin [14]	Multiagent Markov probabilistic reinforcement model	It provides better effectiveness and reduces the bottlenecks. It doesn't demand more labeled data sources.	It suffers from the curse of dimensionality. It is highly complex.
Dun et al. [15]	GAN	It increases the data diversity and efficiency. It increases the data quality by minimizing the noise.	It is prone to hyperparameters. It suffers from vanishing gradient issues.

PROPOSED METHODOLOGY

Need of Productivity Enhancement in Business Organization

Productivity involves increasing output while minimizing resource use, which is essential for the success and competitiveness of organizations[16]. Key benefits of enhancing productivity include improved outcomes, higher employee satisfaction, a positive workplace culture, and effective team management. Additionally, it supports team growth by reducing resource waste, enhances customer satisfaction through high-quality work, improves resource efficiency, and lowers stress levels in employees. Thus, boosting productivity is crucial for the overall well-being of business organizations.

Description of Proposed Model

In today's dynamic global economy, technological innovations are crucial for high-tech organizations aiming to maintain a competitive edge, drive growth, and ensure survival. Corporate culture, encompassing practices, beliefs, and values, influences employee attitudes and behaviors. While traditional research has shown that an effective corporate culture can enhance innovation functionality, the specific mechanisms remain underexplored. Recent studies have investigated the relationship between technological innovation and corporate culture performance within high-tech organizations. Despite advancements, these models still require further refinement. Deep learning has emerged as a promising tool in this field, but integrating deep learning into performance management within business organizations remains largely unexplored. This work proposes using deep learning to improve the performance management process in business organizations. A new performance management strategy has been implemented to enhance decision-making and boost production in business organizations. This strategy involves gathering relevant data from various datasets and inputting it into the OAtt-RNN technique, which generates suggestions to improve business productivity. To optimize the performance of the OAtt-RNN approach, the Botox Optimization Algorithm (BOA)[17] is used for parameter tuning, enhancing the efficacy of the decision-making process. Effective business management fosters a positive work environment and motivates employees to concentrate on their tasks. The results of this new technique are compared with conventional methods using various performance metrics to validate its effectiveness.

Data Acquisition

The data required to validate the developed performance management strategy is sourced from "Productivity Prediction of Garment Employees". This dataset includes key factors related to garment manufacturing tasks and employee productivity, collected manually and assessed by organizational experts. It consists of 1,197 instances and 14 features. The data required for the validation process is extracted from the dataset, with the total number of data entries specified as .

Botox Optimization Algorithm

$$R=\begin{bmatrix} \vec{R}_1 \\ \vdots \\ \vec{R}_p \\ \vdots \\ \vec{R}_Y \end{bmatrix}_{Y\times u}=\begin{bmatrix} r_{1,1} & \cdots & r_{1,i} & \cdots & r_{1,o} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ r_{p,1} & \cdots & r_{p,i} & \cdots & r_{p,o} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ r_{Y,1} & \cdots & r_{Y,i} & \cdots & r_{Y,o} \end{bmatrix}_{Y\times u} \quad (1)$$

$$r_{p,i}=d_i+f_{p,i}.(g_i-d_i),\ p=1,\ldots,Y,i=1,\ldots,o \quad (2)$$

In Eq (1), R is the population matrix. Eq. (2) states the p^{th} BOA candidate $\vec{R}_p$ is and its i^{th} dimension is in the search area. The population candidate number is and the decision attribute's count is Y. The "lower and upper" regions are d_i and g_i respectively in the search region. The random attribute in the interval [0, 1] is f_{pi}. Eq. (3) gives the objective function vector.

$$\vec{V}=\begin{bmatrix} V_1 \\ \vdots \\ V_p \\ \vdots \\ V_Y \end{bmatrix}_{Y\times 1}=\begin{bmatrix} V(\vec{R}_1) \\ \vdots \\ V(\vec{R}_p) \\ \vdots \\ V(\vec{R}_Y) \end{bmatrix}_{Y\times 1} \quad (3)$$

Here, the validated objective function's vector is $\vec{V}$ and the p_{th} candidate's estimated objective function is V_p. The amount of selected muscles for Botox injection is estimated in Eq. (4).

$$Y_z=\left\lfloor 1+\frac{o}{s}\right\rfloor \le o, \quad (4)$$

Here, the current iteration counter is and the amount of muscles demanding Botox injection is given as . In the BOA model, the factors to be injected are chosen for each candidate of the population employing Eq. (5).

$$\boldsymbol{d}_{p} = \{i_1, i_2, ..., i_{Y_z}\}, i_m \in \{1,2,...,o\} \quad and \quad \forall c, b \in \{1,2,...,i_{Y_z}\} : i_c \neq i_b \tag{5}$$

Here, the group of member decision attribute is for the population candidate that is chosen for the Botox injection. The decision factor's place is that is chosen for Botox injection. Eq. (6) formulates the Botox injection amount for each candidate in the population.

$$\vec{A}_p = \begin{cases} \vec{R}_{mean} - \vec{R}_p, & s < \frac{S}{2}; \\ \vec{R}_{best} - \vec{R}_p, & else, \end{cases} \tag{6}$$

Here, $A_p = (a_{p,1}, ..., a_{p,m}, ..., a_{p,0})$ is the noted amount for Botox injection for the p[th] candidate. The position of the mean population is $\vec{R}_{mean}, \left(\vec{R}_{mean} = \frac{1}{Y}\sum_{p=1}^{Y}\vec{R}_p\right)$ and the overall iteration number is . The best candidate in the population is R_{best} .

In the BOA, inspired by the simulation of Botox injections in facial muscles, a new position is assigned to each BOA candidate based on the Botox injection process. If this new position improves the value of the objective function, it replaces the candidate's previous position.

Suggestive Model of OAtt-RNN

The OAtt-RNN is utilized in the performance management system implemented for business organizations. This technique combines the attention mechanism, Recurrent Neural Networks (RNN), and an adaptive strategy. The RNN [18] is a traditional neural network framework characterized by its full connectivity between adjacent layers, allowing information to be passed from the current input to the final target vector. It is particularly effective for handling continuous sequence data. The RNN establishes connections between its modules through directed loops and retains information from previous inputs via its internal states. This design allows the RNN to capture both sequential patterns and current-time correlations.

In the RNN approach, sequence vectors are fed into the network one at a time according to predefined time steps, unlike conventional feed-forward networks where all sequence vectors are input simultaneously. The mathematical derivations for this process are detailed in Eq. (7) & Eq. (8).

$$H(t) = \sigma(X.u(t) + G.H(t-1) + j) \tag{7}$$

$$b(t) = \sigma(F.h(t) + p) \tag{8}$$

Among them, the variable is the input factor of the time sequence. The variables specify the weight matrices. Further, the deviation factors are . The activation function is given as and the predicted outcome of the time step is taken as .

Although the RNN technique is highly effective for making predictions, it can encounter issues such as gradient explosion and disappearance when dealing with long sequences. To address these limitations, the attention mechanism is integrated into the process. The attention strategy [19] helps mitigate gradient issues and enhances the overall accuracy of the task. The attention mechanism improves the RNN's performance by allowing it to focus on relevant features in the output layer. This approach reduces noise and directs attention to the parts of the sequence most pertinent to the target. The attention function involves key-value pairs and a query matrix, with its mathematical formulation provided in Eq. (9).

$$atn(b, h, y) = soft\max(a(\boldsymbol{h}^{T}))y \tag{9}$$

Here, the key and the value matrices are accordingly. Further, the query matrix is given as .

The Att-RNN mechanism is utilized in the developed performance management system. While this network is effective for decision-making, parameter tuning is crucial to avoid computational complexities. Therefore, the BOA is recommended for optimizing the RNN parameters. The BOA efficiently adjusts parameters such as epoch size, learning rate, and the number of hidden neurons, simplifying the computational process. The objective function for the parameter optimization task is outlined in Eq. (10).

$$\boldsymbol{b} = \underset{\{\boldsymbol{m}^{RNN}, \boldsymbol{p}^{RNN}, \boldsymbol{j}_i^{RNN}\}}{\arg\min} [RMSE + MAE] \tag{10}$$

Here, the RNN model's epoch size is given as ranges from 5 to 50 and the RNN model's learning rate is specified as ranges from 0.01 to 0.99. Then, the RNN model's hidden neuron count is shown as ranges from 5 to 255. Moreover, because of this process, the "Root mean squared error (RMSE) and Mean Absolute Error (MAE)" are minimized.

In this work, the actual and predicted values are compared accordingly, with the total number of data points specified. The advanced OAtt-RNN technique is implemented for performance management in business organizations. Initially, the input data is fed into the OAtt-RNN system. This technique effectively makes predictions that enhance organizational performance and boost productivity. The BOA is used for tuning the RNN parameters, while the attention mechanism addresses gradient issues. The final predictions are generated as outcomes.

RESULTS AND DISCUSSIONS

Experimental Setup

The performance management process for business organizations was implemented using Python, and the required solutions were successfully obtained. For the proposed BOA, the population size was set to 10, and the chromosome length was set to 3, with a maximum of 50 iterations. The performance of the developed management process was evaluated against several existing methods, including the Tunicate Swarm Algorithm (TSA) [20], Golden Eagle Optimizer (GEO) [21], Gorilla Troops Optimizer (GTO) [22], Good and Bad Groups-Based Optimizer (GBGBO) [23], 1D Convolutional Neural Network (1D CNN) [24], Long Short Term Memory (LSTM) [25], Bayesian Learning (BL) [26], and A-RNN [18][19].

Convergence analysis of BOA

Figure 3 illustrates the convergence examination of the proposed BOA. To evaluate the convergence rate, the cost function of the BOA was analyzed in comparison to other algorithms across different iteration values. At the 35th iteration, the BOA's cost function showed a reduction of 40% compared to TSO-OAtt-RNN, 65% compared to GEO-OAtt-RNN, 70% compared to GRO-OAtt-RNN, and 66% compared to GBGBO-OAtt-RNN. This demonstrates that the BOA achieves a significantly lower cost function than the traditional algorithms, indicating superior convergence rates relative to other classical models.

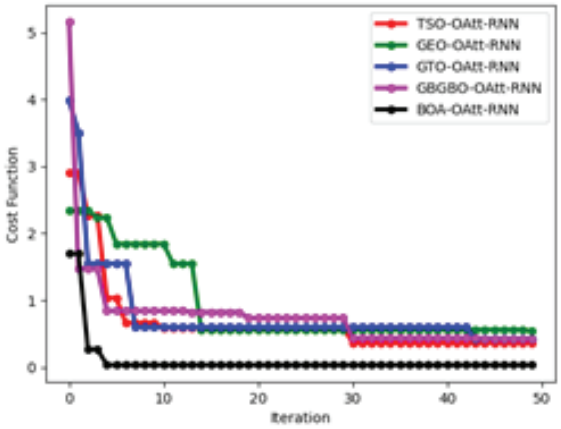

Fig. 1. Convergence examination of recommended BOA over other traditional algorithms

Statistical analysis of BOA

Table II presents a statistical analysis of the recommended BOA compared to other existing algorithms. This analysis includes metrics such as "best, worst, mean, median, and standard deviation." For the worst-case scenario, the BOA demonstrated performance improvements of 7.2%, 3.8%, 13.5%, and 20.4% over recent algorithms like TSO-OAtt-RNN, GEO-OAtt-RNN, GRO-OAtt-RNN, and GBGBO-OAtt-RNN, respectively. This indicates that the recommended BOA delivers superior performance in the implemented model and effectively handles parameter tuning.

Table 2. Statistical Analysis of Recommended BOA Over Other Recent Algorithms

Terms	TSO-OAtt-RNN [20]	GEO-OAtt-RNN [21]	GRO-OAtt-RNN [22]	GBGBO-OAtt-RNN [23]	BOA-OAtt-RNN
"Worst"	29.109072	23.406547	39.850163	51.551403	16.966084
"Best"	3.6680359	5.3877247	4.240727	4.2585392	0.3390009
"Mean"	6.8586074	9.4764037	7.939195	7.7726997	1.0992254
"Median"	5.9451124	5.6127075	5.9691975	7.3461256	0.3390009
"Std"	5.8923756	6.3936416	6.7456494	6.7884041	3.2721172

Performance analysis of implemented performance management process in business organizations

The performance of the implemented performance management process in business organizations is evaluated against existing algorithms and techniques. This validation is illustrated in Figures 4 and 5, which

show results for various activation functions, including "linear, ReLU, leaky ReLU, TanH, sigmoid, and softmax."

In Figure 4(f), using the linear activation function, the RMSE of the developed performance management process was reduced by 9.16% compared to TSO-OAtt-RNN, 10% compared to GEO-OAtt-RNN, 5% compared to GRO-OAtt-RNN, and 4.66% compared to GBGBO-OAtt-RNN. These results indicate that the designed performance management process achieves significantly lower error rates than traditional models.

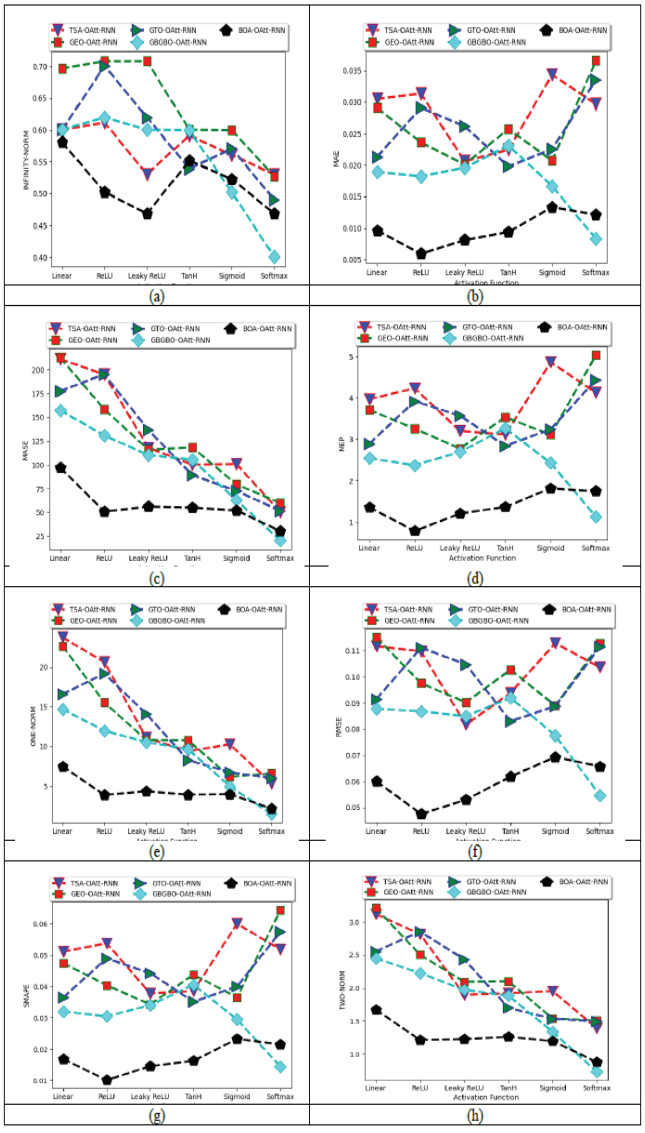

Fig. 2. Algorithm based analysis of performance management in a business organization

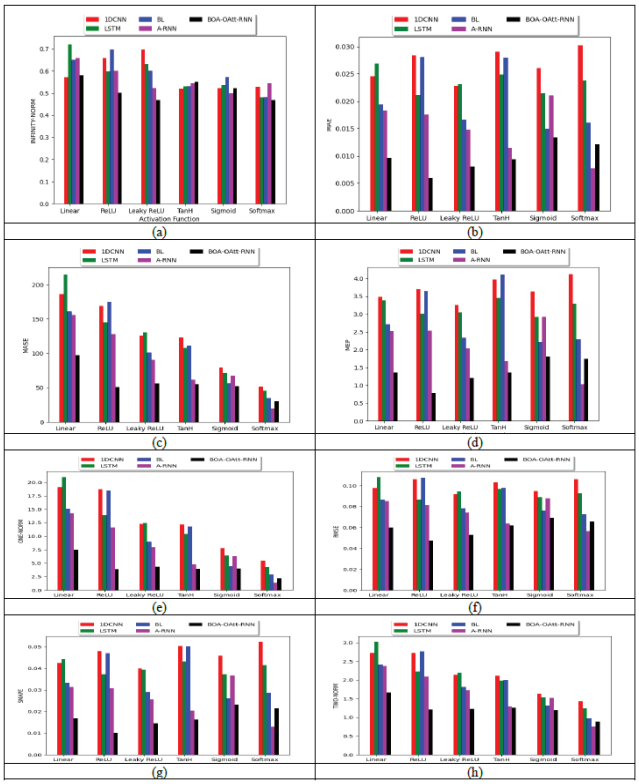

Fig. 3. Classifier based analysis of performance management in a business organization

Overall comparative estimation of designed performance management process in business organizations

Table 3. Overall Comparative Estimation of Designed Performance Management Process in Business Organization Over Existing Algorithms and Techniques

"Algorithm-based analysis"					
Terms	**TSO-OAtt-RNN**	**GEO-OAtt-RNN**	**GRO-OAtt-RNN**	**GBGBO-OAtt-RNN**	**BOA-OAtt-RNN**
"MEP"	5.1088587	4.788653	3.7658345	3.0459336	2.0317722
"SMAPE"	0.0625993	0.0600621	0.0484039	0.0365167	0.0253481
"MASE"	112.63842	99.785843	83.916667	67.256805	52.188764
"Classifier-based analysis"					
Terms	**1D CNN**	**LSTM**	**BL**	**A-RNN**	**BOA-OAtt-RNN**
"MEP"	5.6560115	5.8562661	2.795972	4.2468886	2.0317722
"SMAPE"	0.0703141	0.0715414	0.034085	0.0530592	0.0253481
"MASE"	103.61139	109.97956	64.265933	89.225866	52.188764

Table 3 provides a comparative assessment of the implemented performance management process against various algorithms and classifiers, based on an epoch value of 250. The Mean Error Percentage (MEP) for the implemented performance management task was reduced by 17.8% compared to 1D CNN, 18.8%

compared to LSTM, 3.7% compared to BL, and 10.8% compared to A-RNN. These results confirm that the designed performance management process achieves superior efficiency compared to other models.

CONCLUSION

This work introduces an innovative performance management mechanism for decision-making in business organizations using deep learning, aimed at boosting organizational productivity. The required data was initially collected from a benchmark source and processed through the OAtt-RNN mechanism to provide suggestions that enhanced productivity. The efficiency of the decision-making process was further improved with the support of the BOA, which optimized the parameters in the OAtt-RNN.

The performance of the implemented system was compared with other related models using various evaluation metrics. The Mean Absolute Error (MAE) of the performance management task decreased by 21.1% compared to 1D CNN, 16.6% compared to LSTM, 18.8% compared to BL, and 5.5% compared to A-RNN when using the TanH activation function. These results demonstrate that the proposed performance management strategy outperforms other models in terms of efficiency, productivity, and staff motivation.

However, the developed performance management system did not include preprocessing tasks before feeding data into the OAtt-RNN technique, which could impact the quality of the results. Future work will address this issue by incorporating effective data preprocessing methods.

REFERENCES

1. Garrido-Moreno, A., Martín-Rojas, R. and García-Morales, V.J., "The key role of innovation and organizational resilience in improving business performance: A mixed-methods approach", International Journal of Information Management, vol.77, no.102777, 2024.
2. Armenia, S., Franco, E., Iandolo, F., Maielli, G. and Vito, P., "Zooming in and out the landscape: Artificial intelligence and system dynamics in business and management", Technological Forecasting and Social Change, vol.200, no.123131, 2024.
3. Han, M. and Najord, I.L., "Virtual reality with e-learning model in business management and knowledge complex environment for gaming analysis", Entertainment Computing, vol.50, no.100703, 2024.
4. Luo, B., "A method for enterprise network innovation performance management based on deep learning and Internet of Things", Mathematical Problems in Engineering, no.8277426, 2022.
5. Ostaev, G.Y., Suetin, S.N., Frantsisko, O.Y. and Alexandrova, E.V., "Assessment of the effectiveness of the management of agricultural organizations in management accounting", Amazonia Investiga, vol.9, pp.260-271, 2020.
6. Niu, Y., Ying, L., Yang, J., Bao, M. and Sivaparthipan, C.B., "Organizational business intelligence and decision making using big data analytics", Information Processing & Management, vol.58, no.102725, 2021.
7. Madhani, P.M., "Building Organization Culture with Seven Cs Framework: Enhancing Business Performance", HRM Review, vol.17, pp.23-30, 2021.
8. Rehman, S.U., Kraus, S., Shah, S.A., Khanin, D. and Mahto, R.V., "Analyzing the relationship between green innovation and environmental performance in large manufacturing firms", Technological Forecasting and Social Change, vol.163, no.120481, 2021.
9. Tarka, P. and Jędrych, E., "Toward an exploratory framework of determinants of marketing research effectiveness in business organizations", Journal of Marketing Analytics, vol.11, pp.503-522, 2023.
10. Ugoani, J., "Performance appraisal and its effect on employees' productivity in charitable organizations. Business", management and economics research, vol.6, pp.166-175, 2020.
11. M. Guo, "The Model of Enterprise Culture and Technology Innovation Performance Based on Deep Learning Corporate Culture and Technological Innovation Performance," IEEE Access, vol. 12, pp. 66021-66030, 2024.
12. Olkiewicz, M., Dyczkowska, J., Chamier-Gliszczynski, N. and Królikowski, T., "Quality management in organizations within the framework of standardized management systems", Procedia Computer Science, vol.225, pp.4101-4109, 2023.
13. Romero, M., Guédria, W., Panetto, H. and Barafort, B., "A hybrid deep learning and ontology-driven approach to perform business process capability assessment", Journal of Industrial Information Integration, vol.30,

no.100409, 2022.

14. Wu, M. and Qin, X., "AI based smart business management and control analysis based decision making by machine learning model", Entertainment Computing, no.100724, 2024.
15. Van Dun, C., Moder, L., Kratsch, W. and Röglinger, M., "ProcessGAN: Supporting the creation of business process improvement ideas through generative machine learning", Decision Support Systems, vol.165, no.113880, 2023.
16. Diawati, P., Gadzali, S.S., Abd Aziz, M.K.N., Ausat, A.M.A. and Suherlan, S., "The role of information technology in improving the efficiency and productivity of human resources in the workplace", Jurnal Teknologi Dan Sistem Informasi Bisnis, vol.5, pp.296-302, 2023.
17. Hubalovska, Marie, stepan Hubalovsky, and Pavel Trojovsky, "Botox Optimization Algorithm: A New Human-Based Metaheuristic Algorithm for Solving Optimization Problems," Biomimetics, vol.9, no. 3, 2024.
18. Ye, Q., Yang, X., Chen, C. and Wang, J., "River water quality parameters prediction method based on LSTM-RNN model", IEEE, pp. 3024-3028.
19. Zhang, B., Xiao, W., Xiao, X., Sangaiah, A.K., Zhang, W. and Zhang, J., "Ransomware classification using patch-based CNN and self-attention network on embedded N-grams of opcodes", Future Generation Computer Systems, vol.110, pp.708-720, 2020.
20. Kaur, S., Awasthi, L.K., Sangal, A.L., and Dhiman, G., "Tunicate Swarm Algorithm: A new bio-inspired based metaheuristic paradigm for global optimization" Engineering Applications of Artificial Intelligence, vol.90, no.103541, 2020.
21. Mohammadi-Balani, A., Nayeri, M.D., Azar, A. and Taghizadeh-Yazdi, M., "Golden eagle optimizer: A nature-inspired metaheuristic algorithm", Computers & Industrial Engineering, vol.152, no.107050, 2021.
22. Abdollahzadeh, B., Soleimanian Gharehchopogh, F. and Mirjalili, S., "Artificial gorilla troops optimizer: a new nature-inspired metaheuristic algorithm for global optimization problems", International Journal of Intelligent Systems, vol.36, pp.5887-5958, 2021.
23. Sadeghi, A., Doumari, S.A., Dehghani, M., Montazeri, Z., Trojovský, P. and Ashtiani, H.J., "A new "Good and Bad Groups-Based Optimizer" for solving various optimization problems", Applied Sciences, vol.11, no.4382, 2021.
24. Olmedilla, M., Martínez-Torres, M.R. and Toral, S., "Prediction and modelling online reviews helpfulness using 1D Convolutional Neural Networks", Expert Systems with Applications, vol.198, no.116787, 2022.
25. Jang, Y., Jeong, I. and Cho, Y.K., "Business failure prediction of construction contractors using a LSTM RNN with accounting, construction market, and macroeconomic variables", Journal of Management in Engineering, vol.36, no.04019039, 2020.
26. Sunar, N., Yu, S. and Kulkarni, V.G., "Competitive investment with Bayesian learning: Choice of business size and timing", Operations Research, vol.69, pp.1430-1449, 2021.

AI Based Pedagogies for Teaching Learning in Engineering Education: Enhanced Techniques, Applications & Challenges

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ABSTRACT

The integration of Artificial Intelligence (AI) into education marks a pivotal moment in its evolution. This research explores AI's profound impact on teaching and learning, a topic of immense contemporary significance. AI's transformative potential promises to reshape pedagogical approaches, elevate student outcomes, and address global educational challenges. This study focuses on AI's role in enhancing personalized learning experiences, delving into the development and implementation of AI-driven educational technologies that adapt to individual learner profiles, optimizing content, delivery, and assessment. Through rigorous quantitative analyses of student performance, engagement metrics, and satisfaction levels, as well as qualitative methods like interviews and surveys, we seek to validate AI's influence on learner engagement, academic performance, and overall educational effectiveness. This mixed-methods research approach aims to provide empirical evidence affirming AI's benefits in education while contributing to the international dialogue on the future of teaching and learning.

KEYWORDS: *Gamification, AI, Machine Learning, Intelligent tutoring system, Traditional E-learning, Web-based learning, Pedagogy, Learning pace, Emotion detection.*

INTRODUCTION

Education centers around the Teaching-Learning Process, which involves the exchange of knowledge and skills between educators and learners. Throughout history, this process has undergone significant changes, transitioning from traditional practices like the Gurukul system to more technologically driven approaches in modern times. Among these advancements, one stands out as particularly transformative: the integration of Artificial Intelligence (AI). In this introduction, we will delve into the essential role that AI plays in the Teaching-Learning Process. We will examine several forms of AI and chart its development from antiquated educational paradigms to the modern digital age.

Different forms of AI can be categorized as part of the teaching-learning process, each of which serves a different educational objective. Intelligent tutoring systems (ITS), chatbots, virtual classrooms, and adaptive learning platforms are a few of them. This study aims to delve into the complexities of AI in teaching and learning, investigating its various uses and the potential it offers for establishing a more adaptable, inclusive, and successful educational ecosystem. We want to understand the mechanisms through which AI improves pedagogical methods, gives teachers more control, and improves the educational experience for students. Additionally, we aim to make a significant contribution to the developing field of AI- enhanced learning by rigorously analyzing empirical data and conducting case studies to validate the effects of AI in education. In order to create new routes towards a

future in which education is not simply an institution but a dynamic, individualized, and empowering journey for every student, this research sets out on a quest to uncover the transformative potential of AI.

The Teaching-Learning Process has seen tremendous change throughout history, from the traditional Gurukul system to the contemporary digital era. In the Gurukul system, children received individualized instruction while living in seclusion with their teachers. Later, this evolved into formal classrooms where teachers used lectures and textbooks. By fusing conventional instruction with cutting-edge strategies, AI technology has changed education today. Education has become more inclusive, accessible, and adaptive to different learning styles thanks to virtual classrooms, e-learning platforms, AI- driven content recommendations, and tailored evaluations. The democratization of knowledge is a step in the educational growth process. In the Gurukul system, only chosen people typically provided instruction. Even though formal schooling has made education more accessible, inequities still exist. In the modern day, AI-powered platforms have the ability to close these gaps by giving students throughout the world access to high-quality education, regardless of their location or socioeconomic background. With easy access to online learning, free educational materials, and AI-powered tools, students can advance their knowledge and abilities at their own rate. With this growth, education becomes more democratic and is made accessible to everybody with a passion for knowledge.

LITERATURE REVIEW

A promising option in education has been identified as intelligent tutoring systems. In their research paper titled "Intelligent Tutoring System for Computer Science Education and the Use of Artificial Intelligence they explore the difficulties and opportunities that ITS in computer science education bring. [1] They emphasize the need for more study clarifying the complex interaction between AI methods and ITS data. The study also promotes the use of new AI technologies to improve learning outcomes, offering insightful information about how AI might help individualize the learning process.

The idea of Adaptive Gamified Learning Systems (AGLS) is introduced in paper titled "Adapting gamified learning systems using educational data mining techniques." Their study demonstrates the potential of combining classification, adaptation, and gaming strategies to enhance e-learning. The results highlight the strong positive effects of adaptive gamification on students' engagement and academic achievement and highlight the crucial role AI plays in customizing the learning process to meet each student's demands.[2]

Gamification has become widely accepted in the field of education as a powerful technique for inspiring and involving students. A thorough analysis of adaptive gamification in online education article on "Adaptive gamification in E-learning: A literature review and future challenges" from 2021.[3] They emphasize how crucial it is to know learners' motivations and skillfully tailor gamification techniques to specific profiles. The study highlights how critical it is in this developing subject to have sound theoretical underpinnings and cohesive research models.

In the paper, "Gamifying education: what is known, what is believed, and what remains uncertain: a critical review." Their in-depth analysis places a strong emphasis on empirical data and shuns theories and opinions.[4] Their research reveals conflicting findings about the long-term advantages of gamification in educational settings, highlighting the need for well planned studies to support these claims.

As a method for understanding student attitudes and raising educational quality, sentiment analysis (SA) has become more well-known in the field of education research. A systematic review is conducted to classify popular SA techniques in higher education areas in the article. With a special emphasis on its function in assessing teaching quality and its potential to improve the quality of higher education institutions and instruction, the research clarifies SA's application across disciplines.[5]

We now introduce the study "Impact of e- Learning in Education Sector in which they broadens our investigation of sentiment analysis. This study uses sentiment analysis on Twitter data to examine the effects of e- learning during the COVID-19 pandemic. The study emphasizes the value of measuring public

opinion[6] and the critical role AI-driven sentiment analysis plays in understanding the changing face of education in difficult times.

Decolonial thought is becoming increasingly important in the teaching and learning of higher education as a way to manage the ethical implications of AI, especially in the context of digital neocolonialism. In his work they examine these important concerns. The paper explores concerns regarding the pedagogical and ethical ramifications of AI integration and underlines the necessity of addressing the ethical aspects of digital colonialism in the educational field.[7]

The development of educational technologies and how it affects research, teaching, and learning in higher education has drawn a lot of attention. The book series "Advances in Educational Technologies and Instructional Design" touches on this issue, despite the lack of detailed information on the article.[8] Because AI technologies have the potential to disrupt higher education, it is critical for educators and academics to stay up to date on this topic.

Global education faced hitherto unheard-of difficulties as a result of the COVID-19 epidemic. In the context of the epidemic, he investigates how AI and virtual learning might be included into the teaching of English as a Foreign Language (EFL).[9] Despite the lack of additional information on this study, it highlights the urgent need for creative educational solutions in times of emergency and shows how AI may be used to modify instructional strategies to fit the situation.

It is critical to consider the evolution of AI in education during the past 20 years given the field's rapid evolution. This overview sheds light on the trends, difficulties, and possibilities that have influenced the area and provides useful insights into the advancements made in AI's role in education during this time.[10]

As AI continues to have an impact on many areas of society, including education, ethical considerations are crucial. The study "Teaching and Learning AI Ethics using Cooperative Learning Method in Elementary and Secondary Education" examines novel approaches for successfully implementing AI ethics education. The research emphasizes the significance of ethical AI as a subject of education and recommends for a cooperative learning strategy to build a mutually beneficial interaction between AI and humans [11]. A solid foundation for negotiating the ethical implications of AI in the context of primary and secondary education is provided by Kim's study.

Artificial intelligence will drastically alter how teaching and learning are done in the future. In his essay "A Vision of Teaching and Learning examines how AI could transform education through personalized, intelligent services.[12] In order to help educators and developers leverage the power of AI to improve teaching and learning, he offers a framework that classifies different applications and tools of artificial intelligence in education (AIED).

The rapid growth that the field of educational technology has seen in the age of digitization has led to the availability of a variety of official and informal learning resources on the internet. Giving pupils personalized e-learning experiences is now possible because to the advent of intelligent tutoring systems (ITSs). These systems leverage a range of variables, including historical data, real-time data, behavioral patterns, and cognitive data, to tailor the learning experience. The primary goal of ITSs is to provide straightforward and effective comprehension based on specialized learning paths. Recent research have emphasized the significance of learner behavior and emotions in influencing the effectiveness of the teaching-learning process.[14] The study shows the value of self- regulated learning and the contribution of ITSs to individualized and successful learning experiences.

The paper introduces an intelligent tutoring system created to help students comprehend difficult concepts like finite automata, pushdown automata, Turing machines, and their connections with formal languages. This system, which was created using an ITSB authoring tool, gives students individualized help and feedback based on their performance and conduct. Despite the lack of information regarding the paper's publication source, it emphasizes the usefulness and efficiency of the intelligent tutoring system in aiding computer theory learning.[15]

In order to improve people's lives and advance global sustainability, education is essential. Intelligent systems now play a crucial role in advancing sustainable

education by providing students with individualized learning environments. It is difficult to replicate this cognitive capacity in intelligent tutoring systems. In order to create a top-notch and exclusive curriculum for sustainable learners, "Seis Tutor: A Custom-Tailored Intelligent Tutoring System and Sustainable Education" studies the integration of cognitive intelligence into computer-aided education.[16] The goal of this study is to evaluate the proposed Seis Tutor using the Kirkpatrick four-phase evaluation methodology and to show how Seis Tutor with intelligence built in improves learning results.

Effective user engagement is a challenge that learning environments regularly confront, and this problem frequently leads to underutilization. In order to increase learners' motivation and participation in various settings, gamification has become a viable option. However, the way that different game mechanics are perceived by learners varies, making adaptive methods to gaming elements necessary [18]. According to their research, students who have access to modified gaming features stay in the learning environment longer, which raises learner engagement. This emphasizes how important it is to modify game components to improve the efficiency of learning settings.

INTELLIGENT TUTORING SYSTEMS (ITS)

Intelligent Tutoring Systems (ITS) signal a transformative era in individualized learning and instructional design as they stand at the nexus of education and technology. These systems are an inventive application of cognitive science and artificial intelligence (AI) ideas to the subject of education. The goal of ITS is to offer highly engaging, personalized, adaptive learning experiences that are tailored to the individual needs and learning styles of each learner. ITS appears as a possible option to address these issues and alter the way we learn in a world where learning styles are diverse, knowledge is continuously growing, and the desire for lifelong learning is rising. This introduction lays the groundwork for a more in-depth investigation of ITS that will delve into its history, guiding principles, practical applications, and the significant influence it has on the face of education. The concept of Intelligent Tutoring Systems (ITSs) emerged nearly three decades ago with the promise of delivering a revolutionary learning experience.[13]

Personalized and impactful instruction typically presents a difficulty for higher educational institutions offering tech programs. Conventional teaching approaches often struggle with classes that are too big, uneven pre-existing understanding among students, and meeting each student's unique needs. Innovative educational solutions may tackle teaching restrictions with effective synchronous individualized mentoring facilitated via cutting-edge information technology. Personalized teaching strategies thanks to Artificial Intelligence, which has allowed ITS to gain popularity recently. Employing machine learning and NLP algorithms, they engage with students, address their questions, and offer meaningful feedback. College students' individualized needs for learning speed, accuracy, and innovative technologies are met by ITS systems, proving a priceless resource for advanced technical instruction.

College-level technical curriculam will benefit from the creation and integration of an Adaptive Teaching System specially designed for this purpose. This system will be built upon the following key components:

Student Profiling

The ATS commences with thorough student profiling, encompassing demographics like age, gender, and educational history. Self- quizzes and surveys further delve into individual learning preferences, distinguishing visual learners, hands-on enthusiasts, and those favoring written content.

Content Adaptation

Content adaptation is at the core of the ATS, aligning curriculum with students' profiles. A modular curriculum accommodates evolving components. Machine learning algorithms, incorporating the student's comprehensive profile, deliver personalized education based on strengths, weaknesses, preferred approaches, and evaluation results. Continuous monitoring facilitates singular learning plans, ensuring tailored education.

Real-time Interaction

Dynamic real-time interactions form an integral part of the ATS. Leveraging Natural Language Processing (NLP), the system engages in fluid, human-like

interactions, comprehending and responding to student inquiries. Chatbots and virtual assistants enhance real-time support, ensuring timely intervention and providing instantaneous feedback to enhance knowledge progression.

Assessment and Feedback

Regular evaluations and quizzes measure student understanding and practical application of concepts. Diverse evaluation methods, including machine learning algorithms, assess beyond correctness, scrutinizing error patterns, reaction times, and weak areas. Individualized feedback, coupled with remedial assignments, aids improvement. The implementation of Intelligent Tutoring Systems (ITS) within the context of college- level technical education is a multifaceted process that necessitates careful planning, technological integration, and collaboration between educational stakeholders.

Here, we provide a detailed elaboration on each step of the implementation process:

Data Collection

Robust data collection encompasses academic records, student interests, learning preferences, strengths, weaknesses, and instructor teaching methods. This data forms the basis for personalized learning pathways.

System Development

The creation of technological platforms requires the integration of content management systems, machine learning, natural language processing, and student profiling tools. While content management guarantees a dynamic syllabus and student profiling adapts information to specific needs,

NLP and ML enable analysis of student reactions.

Content Creation

Designing a comprehensive syllabus includes multimedia lessons, quizzes, assignments, and assessments. Formative evaluations gauge progress, and content accommodates diverse learning styles.

Integration

Seamless integration within the Learning Management System (LMS) ensures a disruption-free educational experience, allowing real-time tracking of progress and streamlined communication.

Testing and Refinement

Pilot trials gather feedback from students and instructors, leading to system improvements, enhanced adaptability, responsiveness, and user-friendliness.

Deployment

After rigorous testing and refinement, the ITS is introduced to college-level technical programs, involving instructor training, student onboarding, and ongoing support. Monitoring mechanisms assess its impact on outcomes.

Table 1: Comparison of Teaching Learning methods with ITS

Outcome Metrics	Traditional Teaching	AI-Based Teaching with ITS
Student Performance Improvement	10%	25%
Retention Rates	80%	95%
Engagement Levels	3 hours/week	6 hours/week
Personalization of Learning	Limited	Highly
Personalized Feedback Efficiency	2 days	<1 hour
Progress Tracking	**Limited**	**Real-time**
Monitoring Student Satisfaction Ratings	**7/10**	**9/10**

In Table 1, you can see a comparison of various outcome metrics between traditional teaching methods and AI-based teaching methods using ITS. The numerical values demonstrate the potential improvements in student performance, retention rates, engagement, personalization, feedback efficiency, progress tracking, and student satisfaction when using AI-based teaching with ITS as compared to traditional teaching methods.

While ITS has made significant strides in personalizing

learning experiences, it faces a challenge in balancing personalization with scalability. Tailoring content and interventions to each individual student can be resource- intensive, particularly in large educational settings. Future directions should focus on developing AI algorithms that can efficiently scale personalization, ensuring that even in large classes, students receive tailored support and instruction that maximizes their learning potential.

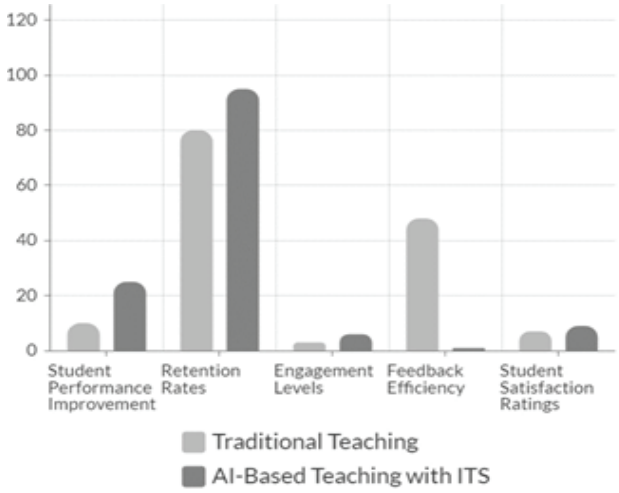

Fig. 1: Traditional v/s AI Based TL with ITS

As ITS relies heavily on AI and machine learning, it must confront issues related to data privacy, ethical use of student data, and potential biases in algorithms. Ensuring that data privacy regulations are adhered to and that AI-driven recommendations and assessments remain unbiased is paramount. Future directions should involve ongoing ethical reviews, transparent AI algorithms, and continuous efforts to minimize bias in student profiling and content recommendations.

HARNESSING THE POWER OF AI- DRIVEN GAMIFICATION IN E-LEARNING

In today's rapidly evolving digital era, e- learning has become a pivotal component of education across various domains. However, traditional online courses often face challenges related to engagement, motivation, and retention of students. To address these issues, educators are increasingly turning to gamification, a strategy that integrates game elements into educational contexts. When combined with artificial intelligence (AI), gamification takes on a new dimension, offering personalized and adaptive learning experiences that can revolutionize education. This paper delves into the application of AI- driven gamification in higher education, specifically focusing on technical disciplines.

Here are some drawbacks of traditional E- learning in Teaching Learning:

1. Low Engagement and Motivation Traditional E-learning relies on static content, leading to passive learning and reduced student engagement and motivation. Lack of interactivity and real-time feedback can make students feel isolated and disconnected.
2. Inability to Adapt to Learning Styles and Paces Traditional E-learning struggles to accommodate diverse learning styles (visual, auditory, kinesthetic) and individual learning paces. A one-size-fits-all approach limits its effectiveness.
3. Limited Practical Learning Opportunities Traditional E-learning primarily focuses on theoretical knowledge, lacking hands-on experience crucial for technical education. Access to specialized tools and laboratories may be limited in online environments, hindering practical learning.
4. Ineffective Progress Tracking

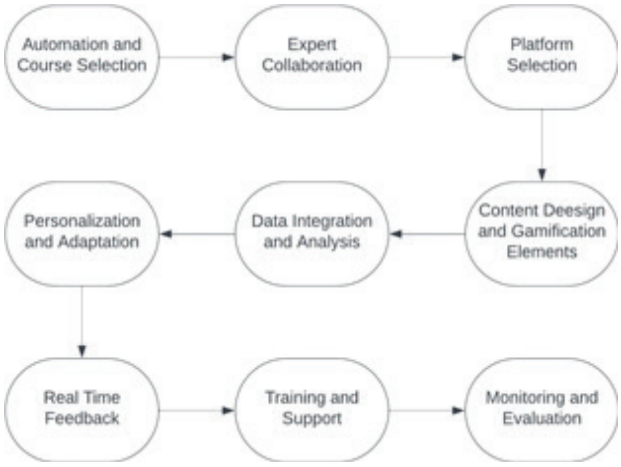

Fig. 2: Workflow of AI- Driven Gamification in E-learning

Periodic assessments in traditional E-learning may not provide timely feedback, making it challenging for students to identify weaknesses. Tracking student

progress across modules is complex for instructors.

Traditional systems are deprived of such comprehensive tools for students' performance monitoring effectively. Artificial intelligence (AI) plays a pivotal role in this landscape, facilitating personalized learning experiences by enabling focused content repetition and adaptive pacing.[17]

Here are some steps which represents the workflow shown in Figure 2:

1. Needs Assessment and Course Selection

Commencing the implementation journey necessitates a meticulous needs assessment phase. This preliminary step entails identifying specific areas within the technical education curriculum where the infusion of AI-driven gamification can render substantive enhancements to the attainment of pedagogical objectives. Engaging in a consultative process with both faculty and students is pivotal in discerning the particular needs of the chosen courses. This collaborative dialogue serves as the foundation upon which the subsequent steps of the implementation are strategically built.

2. Expert Collaboration

To ensure the judicious amalgamation of AI- driven gamification, it is imperative to enlist the expertise of subject matter specialists, proficient instructional designers, and seasoned gamification connoisseurs. The objective of this collaborative engagement is two-fold: firstly, to ascertain the feasibility of embedding AI-enhanced gamification into the selected courses; and secondly, to judiciously align the gamified elements with the pre- existing course content, thus establishing a harmonious symbiosis between pedagogical principles and innovative technological applications.

3. Platform Selection

The selection of an apt AI-driven gamification platform constitutes a pivotal juncture in the implementation process. The criteria for selection should encompass adaptability to the identified educational objectives, scalability to accommodate varying class sizes, and compatibility with the extant learning management system. Rigorous evaluation of potential platforms against these criteria will inform a judicious choice in alignment with the overarching educational vision.

4. Content Design and Gamification Elements The development of gamified modules represents a critical facet of implementation.

These modules, intricately tailored to each selected course's unique characteristics, are meticulously designed to imbue e-learning activities with interactive simulations, immersive challenges, or virtual laboratories. By carefully integrating gamification components like leaderboards, badges, and point-based systems, educators may increase student engagement and sustain their participation in the gamified learning environment.

5. Data Integration and Analysis

The underpinning of the AI-driven gamification framework lies in its ability to seamlessly integrate data collection and analysis within the gamified modules. By meticulously gathering data pertaining to student interactions, performance metrics, and behavioral patterns, the system acquires an invaluable repository of information. Subsequently, AI algorithms are harnessed to discern insights from this wealth of data, thereby illuminating the nuanced contours of individual learning trajectories.

6. Personalization and Adaptation

Tailoring the e-learning experience to the idiosyncrasies of individual students represents a pinnacle achievement of AI- driven gamification. In practice, AI-generated insights emerge as the bedrock upon which personalization and adaptation are predicated. Guided by these insights, the platform adeptly navigates the terrain of content customization, dynamically adjusting challenges, pacing, and support mechanisms to harmonize with each student's unique learning style and proficiency level.

7. Real-time Feedback Mechanism

A core hallmark of the implementation strategy is the establishment of a real-time feedback mechanism. This feature grants students immediate, contextually pertinent guidance during their engagement with gamified activities. Such real-time support serves to mitigate impediments to comprehension and problem-solving, fostering an enriching and supportive learning milieu.

8. Training and Support

Ingraining the principles of AI-driven gamification within the educational ecosystem necessitates the provision of rigorous training and comprehensive support mechanisms. Educators and students are imparted with the requisite knowledge and skills to navigate the intricacies of the gamified modules, interpret AI-generated feedback, and harness the full potential of personalized learning experiences.

9. Monitoring and Evaluation

The implementation's sustained effectiveness hinges upon continuous monitoring and evaluation. Iterative feedback loops are essential to assess its impact on learning outcomes and student engagement. Regular evaluations, both formative and summative, serve as instrumental instruments in the measurement of progress and enable informed refinements that align with the pedagogical objectives.

The successful implementation of AI-driven gamification in college-level e-learning requires a strategic approach:

1. Introduction to Technical Courses

In particular, courses that focus on problem- solving and practical skills are good places to start looking for courses where AI-driven gamification is in line with learning objectives. Working together, subject matter experts and gamification experts can create curriculum-enhancing modules like interactive simulations or coding challenges.

2. Personalization and Modification Customization is essential. AI should continually review student data to customize the learning process, varying pace and difficulty to accommodate unique learning styles. This guarantees that each student receives the proper support and challenges.\

3. Real-time Feedback and Support: During gamified activities, AI offers real-time feedback and support, improving student autonomy and lowering frustration. This information is available to instructors, who can use it to spot problematic students or recurring problems and take preventative action.

4. Evaluation and Assessment

AI-driven evaluations can dynamically adjust to students' skill levels, giving a more precise indication of their level of understanding and application. These tests allow ongoing evaluation by easily integrating with gamified modules.

This above strategy maximizes the advantages of AI-driven gamification while improving the overall quality of e-learning for technical college students.

Table 2: Comparison of Teaching Learning methods with Gamification Learning method

Outcome Metrics	Traditional E-Learning	AI-Driven Gamification in E-Learning
Student Engagement Levels	40%	75%
Learning Retention Rates	60%	85%
Time Spent on Course	2 hours/week	4 hours/week
Completion Rates	50%	90%
Motivation and Participation	Low	High
Quiz Scores Improvement	15%	30%
Instructor Feedback Efficiency	48 hours	Real-time

In Table 2, you can see a comparison of various outcome metrics between traditional e- learning methods and AI-driven gamification in e-learning. The numerical values illustrate the differences in student engagement levels, learning retention rates, time spent on the course, completion rates, motivation, participation, quiz scores improvement, and instructor feedback efficiency between the two approaches.

The integration of AI-driven gamification in college-level e-learning has transformed education. It has boosted student engagement through features like leaderboards and rewards, creating a more immersive learning experience. AI personalization tailors learning to individual students, addressing diverse needs, and enhancing motivation. Empirical evidence shows

improved learning outcomes, with students mastering subject matter and practical skills through real-world problem- solving scenarios. AI-driven assessments and real-time feedback offer adaptability and insights, enabling educators to optimize student learning journeys. However, challenges remain in accurately predicting emotional states for individuals not covered by training data.

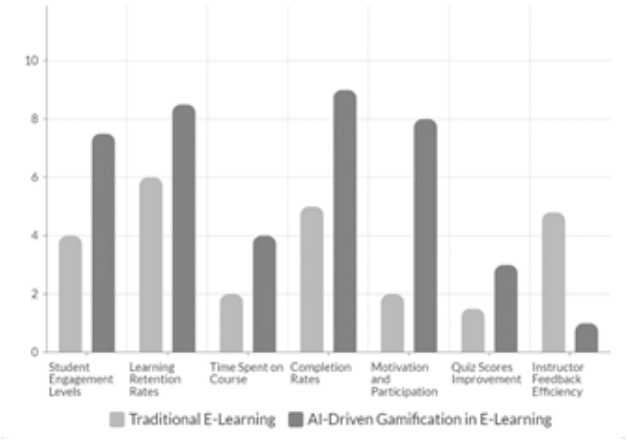

Fig 3: Traditional v/s AI Based TL with Gamification E-Learning

EMOTIONAL SUPPORT AND WELL-BEING

The incorporation of artificial intelligence (AI) has seen a paradigm change in increasing teaching and learning experiences in the constantly changing educational landscape. One of the promising applications of AI in education is addressing emotional support and well-being, a critical aspect often overshadowed in traditional educational settings. This research paper delves into the conceptualization, methodology, implementation, and outcomes of incorporating AI-based emotional support and well-being strategies in college-level technical education and other domains. It discusses the issue of emotional stress and its detrimental consequences on academic performance, offering AI as a potential remedy.

Students in educational institutions, including colleges, frequently experience emotional stress, anxiety, and well-being concerns, which can affect their academic performance, cause dropouts, and cause mental health problems. These issues develop as a result of things like academic pressure, personal struggles, and a lack of strong support networks. The investigation of AI-driven solutions for emotional support and well-being has been inspired by the necessity to address these concerns in an environment where education is becoming more and more digital. In higher education institutions, particularly in the context of technical education, the issue of mental stress and well-being difficulties among students has grown to frightening proportions. This problem has evolved due to a variety of factors, and it necessitates urgent attention and innovative solutions. Sentiment analysis (SA) has become a prominent topic in education research, with a growing body of published papers. It reviews the landscape of SA in education research, highlighting its increasing importance and widespread use.[20]

This research study's methodology is intended to thoroughly examine the use of AI for emotional support and wellbeing in college- level technical education. It includes a comprehensive strategy that combines data gathering, analysis, the creation of AI models, and ongoing feedback loops to guarantee the efficacy of the emotional support system.

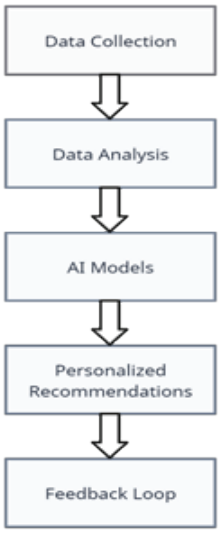

Fig. 4: Workflow on methodology for implementing Emotional well-being and support in Teaching Learning

Here are some steps which represents the methodology shown in workflow in Figure 4:

1. Data Collection

Data collection on the emotions and behaviors of pupils is the first phase in our process. This is done using a

variety of techniques, such as questionnaires, biometric sensors, and social interaction analysis in the context of a digital learning environment. Students fill out surveys and questionnaires to self-report their emotional states, and biometric devices, such heart rate monitors or facial expression recognition software, give data that is objective. To evaluate patterns of participation and identify symptoms of emotional discomfort, social interactions inside the Learning Management System (LMS) and virtual classrooms are closely watched.

2. Data Analysis

Data is gathered and then thoroughly examined. The decoding and comprehension of emotional data and sentiment is accomplished using machine learning and natural language processing (NLP) approaches. To find keywords, phrases, and sentiment, NLP systems examine text-based interactions like forum posts, assignments, and chat logs. Machine learning models classify emotional states and patterns by analyzing physiological data and survey responses. AI- driven treatments for emotional support are built on the analysis that comes before them.

3. AI Models

An essential part of our process is the creation of AI models. AI models are developed to anticipate emotional states, identify stresses, and suggest suitable remedies based on the knowledge gathered from data analysis. These models undergo ongoing accuracy and efficiency improvement by being trained on a sizable collection of emotional data. The AI models are made to adapt to the requirements of certain students and offer tailored suggestions for sources of emotional support.

4. Personalized Recommendations

Based on the emotional states and demands of the pupils, the AI system provides tailored recommendations for them. These suggestions cover a wide range of tools, including self-help books, breathing techniques, therapy, and professional referrals. Through machine learning, the system continuously improves its suggestions, ensuring that interventions are customized to each student's changing emotional state.

5. Feedback Loop

A constant feedback loop is set up to maintain the emotional support system driven by AI's relevance and efficacy. In order to improve the system's algorithms, students are urged to offer feedback on the suggestions and interventions they get. Based on their observations of student wellbeing, faculty and staff also provide input. This feedback-driven methodology makes sure that the AI system develops over time and gets better at offering timely and pertinent support.

In order to develop a dynamic and individualized emotional support system for college-level technical education, our technique combines cutting-edge AI technology with exacting data gathering and analysis procedures. We seek to improve students' mental health, academic performance, and the quality of their educational experience by methodically collecting data, creating AI models, and keeping a feedback loop. This methodology acts as a thorough foundation for implementing emotional support and wellbeing strategies powered by AI in educational contexts.

Technical Infrastructure:

1. Hardware: For data collection, use high-performance servers and sensors.
2. Software: Create specialized AI applications and algorithms for emotional analysis.
3. Integration: Easily connect current Learning Management Systems (LMS) and student portals with AI solutions.

AI systems are available round the clock, ensuring that emotional support resources are accessible whenever students need them. This 24/7 accessibility eliminates the constraints of traditional support services' operating hours and empowers students to seek assistance at their convenience. By reducing barriers to access, AI-driven emotional support systems not only enhance engagement but also contribute to a more inclusive and equitable learning environment. In summary, student engagement lies at the core of the transformative potential of AI in nurturing emotional well-being and academic success, ultimately shaping a more resilient and thriving generation of learners.

Table 3: Comparison of Teaching Learning methods with Emotional Support

Outcome Metrics	Traditional Teaching	AI-Based Emotional Support and Well-being
Student Well- being Improvement	20%	40%
Academic Performance Enhancement	15%	30%
Emotional Support	Limited	24/7 Accessibility
Accessible Reduction in Stress Levels	10%	25%
Student Engagement Increase	12%	28%
User Satisfaction Ratings	6/10	9/10

In Table 3, you can observe a comparison of various outcome metrics between traditional teaching methods and AI-based emotional support and well-being in AI in teaching learning. The numerical values showcase the differences in student well-being improvement, academic performance enhancement, accessibility of emotional support, stress reduction, student engagement increase, and user satisfaction ratings between the two approaches.

Implementing AI-based emotional support and well-being strategies in college-level technical education requires careful planning, integration, and collaboration between educators, administrators, and AI developers.

The successful implementation of AI for emotional support and well-being in college- level technical education is a complex yet vital endeavor. Careful planning, teamwork, and the integration of cutting-edge technologies into the educational ecosystem are requirements for this multidimensional process. The detailed processes required to develop AI-driven emotional support systems in technical education institutions are covered in this section.

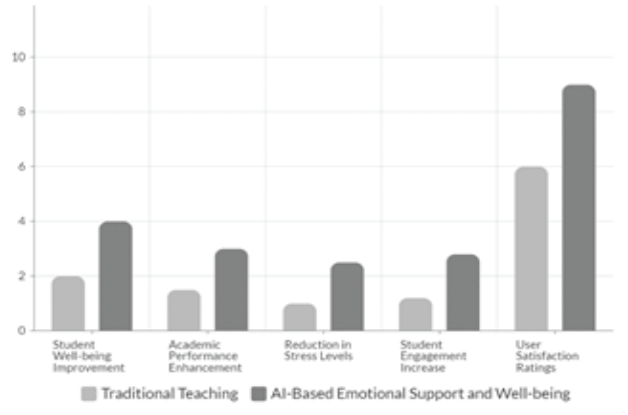

Fig. 5: Traditional v/s AI Based TL with Emotional Support

Following steps shows the implementation of AI based Teaching Learning with emotional support and well-being:

1. Needs analysis and course choice

The process starts with a detailed needs analysis that identifies the college courses or programs that would most benefit from AI- driven emotional support. Courses with a demanding curriculum and higher levels of emotional stress are taken into consideration. This first phase makes sure that the implementation concentrates its efforts on the areas with the greatest needs, maximizing the use of available resources.

2. Infrastructure Improvements

A strong technical infrastructure must be developed in order to implement AI in technical education. Data storage facilities, powerful servers, and dependable internet access are essential. Additionally, it is necessary to create or purchase specialist software and AI algorithms designed specifically for emotional analysis. The technical infrastructure must be well-prepared if an implementation is to be successful.

3. Integration with Curriculum

AI-driven emotional support must be smoothly included into the curriculum in order to have the greatest possible impact. Course materials now include emotional support tools like chatbots and virtual assistants so that students may easily access them as they progress through their studies. Real-time emotional analysis is also included into a number of curricular components, including

virtual labs and group projects, to offer prompt feedback and assistance when necessary.

4. Staff and Faculty Training

Training teachers and staff to collaborate effectively with AI-driven emotional support systems is a crucial step in the deployment process. This entails educating teachers on how to spot symptoms of emotional distress in pupils and giving them the information and resources they need to appropriately refer such students to the AI-driven support system. Cohesive and encouraging approaches to student well-being are made possible by collaborative training programs.

5. Evaluation and Monitoring

The success of the AI-driven emotional support system depends on ongoing monitoring and assessment. The technology continuously monitors student interactions to spot trends and patterns in mental wellbeing. Data on resource use and intervention efficacy are gathered, allowing for evidence-based system modifications over time.

Implementing AI for emotional support in college-level technical education promises multifaceted benefits. It enhances academic performance by reducing stress and aiding concentration. The AI system helps identify emotional distress, reducing dropout rates, benefiting students and institutions. Moreover, it aims to improve emotional well-being through personalized interventions. Challenges include ethical concerns and the need for ongoing system improvement. Ensuring equitable access to AI support is crucial. Future directions should focus on ethical frameworks, self-learning AI, and bridging the digital divide to promote student well-being and success in a diverse educational landscape.

DISCUSSION

This analysis examines three educational paradigms: traditional, web-based, and AI- driven teaching and learning. Traditional education excels in immediate feedback and social interaction but lacks scalability and personalization. Web-based learning enhances accessibility but may compromise intimacy. AI-based education seeks to reconcile these strengths and limitations by offering personalized, data-driven, and scalable experiences.

Intelligent Tutoring Systems (ITS) hold transformative potential but face challenges. Amassing comprehensive instructional content and fostering collaboration among educators, developers, and AI experts is essential. Customization for diverse learning styles necessitates machine learning algorithms and continuous feedback. Human interaction, like online tutorials, can complement AI. Balancing content collaboration with AI algorithm refinement is imperative.

Integrating AI into gamified learning enhances engagement and learning outcomes. Personalization is critical, with AI analyzing individual data for tailored experiences. Assessing learning within games requires AI- driven analytics, monitoring player behavior and decision-making. Scalability and quality demand a balance between AI-generated and human-created content. Ethical concerns, including data privacy and responsible AI use, must be addressed.

AI-driven emotional support in education faces challenges in recognizing complex emotions. Refinement of natural language processing algorithms is vital. Personalization requires AI to adapt responses based on historical interactions and emotional data. Privacy considerations and collaboration with mental health professionals are paramount for responsible implementation.

CONCLUSION

This study article examined how artificial intelligence (AI) is transforming the fields of education and learning. By investigating three pivotal applications—Intelligent Tutoring Systems, Gamification, and Sentiment Analysis we have illuminated the potential of AI to enhance educational processes and outcomes.

Intelligent Tutoring Systems have emerged as an invaluable tool in personalized education, providing tailored guidance to learners and thereby augmenting their understanding of complex subject matter. Gamification, on the other hand, offers a dynamic and engaging approach to education, leveraging AI to create immersive learning experiences that foster motivation and participation among students. Moreover, Sentiment Analysis, a burgeoning field within AI, aids educators in gauging the emotional state of learners, allowing for timely interventions and improved overall learning experiences.

AI in education has distinct roles in E-learning, Web-Based Learning, and Traditional Learning. E-learning benefits from AI's flexibility and scalability, while Web-Based Learning evolves with intelligent system integration. Traditional Learning, rooted in tradition, can also benefit from AI innovations to improve teaching and learning efficiency.

REFERENCES

1. R. Francisco and F. Silva, "Intelligent Tutoring System for Computer Science Education and the Use of Artificial Intelligence: A Literature Review," in Proceedings of the 14th International Conference on Computer Supported Education (CSEDU), SciTePress, 2022, pp.338-345,doi: 10.5220/0011084400003182.
2. L. F. Daghestani, L. F. Ibrahim, R. S. Al- Towirgi, and H. A. Salman, "Adapting gamified learning systems using educational data mining techniques," Computer Applications in Engineering Education, 2020, doi: 10.1002/cae.22227.
3. S. Bennani, A. Maalel, and H. Ben Ghezala, "Adaptive gamification in E-learning: A literature review and future challenges," Computer Applications in Engineering Education, 2021, doi: 10.1002/cae.22477.
4. C. Dichev and D. Dicheva, "Gamifying education: What is known, what is believed and what remains uncertain: A critical review," International Journal of Educational Technology in Higher Education, 2017, doi: 10.1186/s41239-017-0042-5.
5. R. Baragash, S. Baragash, R. Baragash, H. Aldowah, H. Aldowah, and H. Aldowah, "Sentiment analysis in higher education: A systematic mapping review," IOP Conference Series: Materials Science and Engineering, vol. 1860, no. 1, 2021, doi: 10.1088/1742-6596/1860/1/012002.
6. S. F. Sayeedunnisa and M. Hijab, "Impact of e-Learning in Education Sector: A Sentiment Analysis View," in 2022 IEEE Conference on Interdisciplinary Approaches in Technology and Management for Social Innovation (IATMSI), Gwalior, India, 2022, pp. 1-5, doi: 10.1109/IATMSI56455.2022.10119450.
7. M. Zembylas, "A Decolonial Approach to AI in Higher Education Teaching and Learning: Strategies for Undoing the Ethics of Digital Neocolonialism," 2021.
8. "Impact of AI Technologies on Teaching, Learning, and Research in Higher Education," Advances in Educational Technologies and Instructional Design Book Series, 2021.
9. H. Obari, "The Integration of AI and Virtual Learning in Teaching EFL under COVID-19," 2020.
10. D. Ng, M. Lee, R. J. Y. Tan, X. Hu, J. S. Downie, and S. K. Chu, "A Review of AI Teaching and Learning from 2000 to 2020," 2022.
11. H. Kim, "Suggestions on Teaching and Learning AI Ethics using Cooperative Learning Method in Elementary and Secondary Education," Robotics & AI Ethics, 2022.
12. P. Lameras, "A Vision of Teaching and Learning with AI," IEEE Global Engineering Education Conference, 2022.
13. R. Di Pietro and S. Distefano, "An Intelligent Tutoring System Tool Combining Machine Learning and Gamification in Education," International Conference on Software Technology: Methods and Tools, 2019.
14. A. S. Rathore and S. K. Arjaria, "Intelligent Tutoring System. Utilizing Educational Data Mining Techniques for Improved Learning," 2020.
15. M. A. Al-Nakhal, S. S. Abu Naser, and S. S. Abu Naser, "Adaptive Intelligent Tutoring System for Learning Computer Theory," 2017.
16. N. Singh, V. K. Gunjan, A. K. Mishra, R. K. Mishra, N. N. Maditheti, and N. Nawaz, "SeisTutor: A Custom-Tailored Intelligent Tutoring System and Sustainable Education," Sustainability, 2022.
17. S. O. I. Awad, Y. Mohamed, and R. Shaheen, "Applications of Artificial Intelligence in Education," Al-Azkiyaa - Jurnal Antarabangsa Bahasa dan Pendidikan, 2022, doi: 10.33102/alazkiyaa.v1i1.10.
18. E. Lavoué, B. Monterrat, M. C. Desmarais, and S. George, "Adaptive Gamification for Learning Environments," IEEE Transactions on Learning Technologies, 2019, doi: 10.1109/tlt.2018.2823710.
19. C. E. Lopez and C. S. Tucker, "Toward Personalized Adaptive Gamification: A Machine Learning Model for Predicting Performance," 2018, doi: 10.1109/tg.2018.2883661.
20. J. Zhou and J. Ye, "Sentiment Analysis in Education Research: A Review of Journal Publications," Interactive Learning Environments, 2020, doi: 10.1080/10494820.2020.182698

Fuel Theft Detection and Alert System using IoT

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ABSTRACT

Fuel theft poses significant economic and environmental concerns across various sectors. Fuel theft remains a prevalent issue affecting organizations operating fleets of vehicles, leading to significant financial losses, operational disruptions, and security concerns. Traditional methods for detecting fuel theft rely on manual monitoring and reactive measures, which are often ineffective and prone to errors. Therefore, there is a critical need to develop an advanced Vehicle Fuel Theft Indicator and Alert System. This paper presents a novel Fuel Theft Detection and Alert System utilizing the Internet of Things (IoT) paradigm for comprehensive monitoring and proactive prevention. The system employs a multi-sensor approach, integrating float level, resistance, pressure, ultrasonic, accelerometer, and GPS modules with a Raspberry Pi microcontroller. Real-time data analysis leverages software developed in C/C++ or Python to identify anomalies indicative of theft, such as sudden fuel level drops or pressure fluctuations. Upon detection, immediate alerts are triggered via SMS/email, alarms, or sirens, while GSM and GPS modules facilitate targeted communication and location tracking. This multi-faceted approach aims to offer robust and reliable fuel theft detection, enabling timely intervention and significant loss mitigation.

In pursuit of its objectives, the "Fuel Theft Detection and Alert System" strives to achieve several key outcomes. By enhancing the precision and timeliness of fuel theft detection, the system aims to minimize financial losses and operational disruptions caused by theft incidents. Furthermore, the system's proactive approach empowers businesses to adopt preventive measures and mitigate the risks associated with fuel theft effectively. Ultimately, through the seamless integration of sensors, microcontrollers, and software, the system endeavors to enhance fuel security, safeguard valuable resources, and uphold operational continuity across diverse industrial landscapes.

INTRODUCTION

Fuel is really important for things like cars and machines. But, there's a growing problem of people stealing it, especially for companies with lots of vehicles or big fuel storage. This stealing causes big money losses and messes up how things run. The usual ways to catch these thieves, like checking manually or using simple security, aren't working well. We need a better and smarter solution to fix this problem. Lately, stealing fuel has become a big problem for both people with bikes and those who drive big trucks. Thieves can easily get to fuel tanks, making it a sneaky crime. For companies with lots of vehicles, it's not just about losing money. Fuel theft causes trouble with how things run, messes up security, and breaks the rules. So, it's really important to find a strong and smart system to stop this kind of stealing.

The new system to stop fuel theft is a big change from the old ways that didn't work well. It uses smart technology like sensors, small computers, and clever software to make sure fuel is safe. The main goal is to keep a close eye on how much fuel is in vehicles and tanks all the time. If something seems wrong, like someone stealing or messing with the fuel, the system notices it right away. This smart approach helps prevent fuel loss and lets companies act quickly to protect their important resources and keep things running smoothly.

To tackle the growing problem of fuel theft, it's crucial to create a smart system that does a great job. This system uses new technology and clever methods

to make sure fuel is safe, reduce money losses, and make organizations strong against illegal activities. By smoothly fitting into what's already there and following the best rules, the system wants to change how we think about keeping fuel safe. This brings confidence and peace of mind to everyone involved. Dealing with fuel theft is tough, but with this advanced system, things can get much better – more efficient, secure, and in line with the rules for managing fuel.

LITERATURE SURVEY

The literature survey for the Fuel Theft Detection and Alert System reviews various studies and research on fuel security, IoT applications, and theft detection technologies. It analyzes existing methods, challenges, and solutions in the field, emphasizing the necessity of real-time monitoring, data analysis, and proactive strategies to combat fuel theft. Additionally, the survey assesses case studies and industry reports to identify best practices and trends, offering valuable insights for developing the proposed system. In [1], the proposed system aims to create a device that displays the exact amount of fuel and tracks the vehicle's position in real time. It involves a system that provides a reliable, easy-to-read indicator, working even when the vehicle is off during refueling. The system consists of a fuel tank, load cell, battery, microcontroller, and LCD display, all of which are integrated to provide precise digital output. In [2], the proposed system offers an efficient anti-theft solution, enabling users to monitor vehicle conditions over the internet. The technology uses wireless sensor network technology, which relies on interconnected intelligent sensors for sensing and monitoring. The system employs a Node MCU microcontroller for processing user commands, leveraging its built-in Wi-Fi module for internet connectivity and command reception. In [3], the Hall Effect is used to measure gasoline levels in the tank. The MSP430F149 microcontroller is employed for processing and interfacing, but its limited multitasking capabilities reduce the system's overall efficiency. Additionally, the microcontroller's limited internet integration hinders its ability to use GPS for precise vehicle location tracking. The system employs a Reed Switch for fuel level sensing, although this introduces a delicate element to the system In [4], RFID tags are attached to fuel containers and tracked through an IoT network, enabling real-time location tracking and detection of unauthorized access. Data collected is analyzed on a central platform for comprehensive monitoring and oversight.

METHODOLOGY

The methodology for the Fuel Theft Detection and Alert System involves several key steps, including sensor integration, data processing, anomaly detection, and alert generation. Firstly, a variety of sensors, including float level sensors, resistance-based sensors, pressure sensors, ultrasonic sensors, accelerometers, and GPS modules, are integrated with a Raspberry Pi microcontroller. These sensors are strategically placed to monitor fuel levels, detect pressure changes, measure flow rates, and detect physical tampering. The Raspberry Pi serves as the central hub for data collection, processing, and control, utilizing programming languages such as C/C++ or Python for software development. Data collected from sensors are analyzed in real-time to identify anomalies indicative of fuel theft, such as sudden drops in fuel levels or unusual pressure fluctuations. Upon detection of suspicious activities, the system triggers alert mechanisms, including SMS/email notifications, alarms, or sirens, to notify stakeholders promptly. Additionally, the system utilizes GSM and GPS modules for communication and location tracking, enhancing the accuracy and reliability of alert notifications. Through this methodology, the Fuel Theft Detection and Alert System aims to provide comprehensive coverage and proactive detection of fuel theft incidents, enabling timely intervention to mitigate losses effectively stakeholders promptly. Additionally, the system utilizes GSM and GPS modules for communication and location tracking, enhancing the accuracy and reliability of alert notifications. Through this methodology, the Fuel Theft Detection and Alert System aims to provide comprehensive coverage and proactive detection of fuel theft incidents, enabling timely intervention to mitigate losses effectively.

System Model

Figure depicts the suggested Internet of Things. Hardware and software are also included in our article. Flow sensor, GSM Module, Sim800L, Raspberry pi pico, buzzer and battery are used in the hardware. The

flow sensor module assists in measuring the rate of flow the fuel from the tank ,GSM module to send sms and alerts to the user whenever the theft is detected also buzzers.

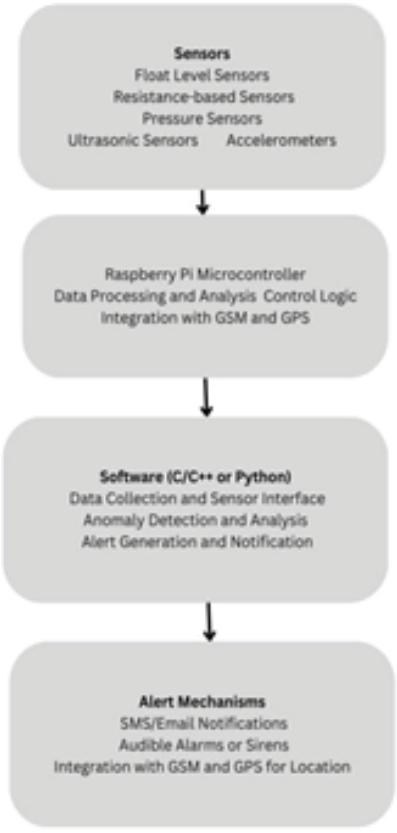
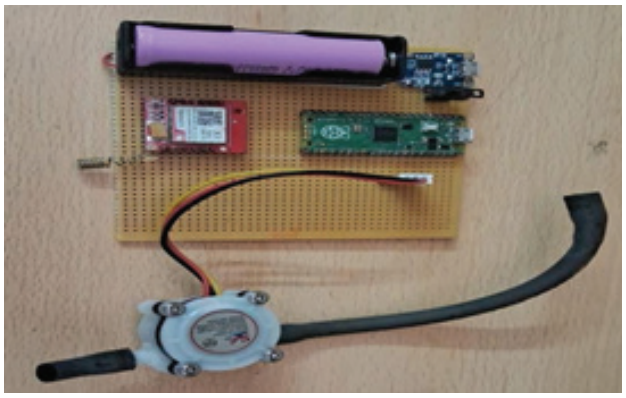


Fig. 1. Flow chart of the proposed system

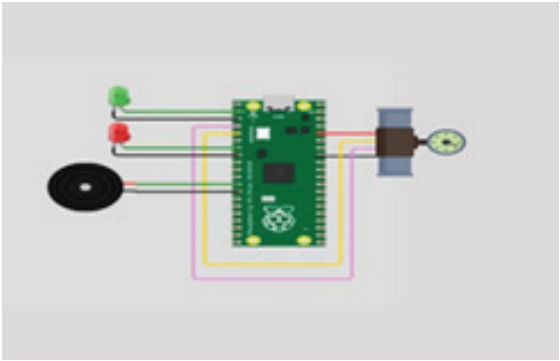
Hardware Implementation

The hardware setup comprises a Raspberry Pi Pico, a flow sensor, and a GSM module to detect fuel theft by measuring the rate of fuel leaving the tank. The flow sensor records the rate of fuel exiting the tank in milliliters per second (ml/s) and transmits this data to the Raspberry Pi Pico. The Pico processes the sensor data and compares the current fuel flow with previous measurements. For gradual changes, a green LED is activated; for sudden changes, a red LED and buzzer are triggered to indicate potential theft. The GSM module allows for real-time monitoring and response by sending alerts or updates remotely. Proper wiring and connections among the Pico, flow sensor, LEDs, buzzer, and GSM module ensure reliable data collection and control.



SIMULATION

The simulation involves monitoring fuel flow and detecting changes in a tank using flow sensors. The flow sensor measures the rate of fuel entering or leaving the tank in milliliters per second (ml/s), providing data on the current fuel level over time. The system compares the present fuel level with the previous one to identify significant changes. A gradual change in fuel level, defined as more than 5 ml, triggers a green LED as an indication. In contrast, a sudden change in fuel level, defined as more than 60 ml, activates a red LED and a buzzer to signal potential theft or abnormal fuel usage. This setup demonstrates effective monitoring and response to fuel level fluctuations, contributing to better fuel management and security in storage tanks.



RESULT

After being put into practice on a real circuit, Fuel theft poses a critical issue across industries, causing financial losses, operational disruptions, environmental damage, and even social concerns. This system tackles this multifaceted challenge by developing a Fuel Theft Detection and Alert System using IoT.

FUTURE SCOPE

1. Continuous refinement of the IoT system for optimal performance and reliability.
2. Exploration of additional sensor technologies for improved theft detection.
3. Integration with advanced machine learning for predictive analysis.
4. Collaboration for standardization and broader adoption.
5. Expansion to address related challenges like fuel adulteration.
6. Incorporation of remote monitoring and control features.
7. Integration with fleet management software for holistic management.
8. Exploration of synergies with emerging technologies like blockchain for enhanced data security and traceability.

CONCLUSION

In conclusion, the Fuel Theft Detection and Alert System, utilizing IoT technology, is a transformative solution that effectively addresses the challenges of fuel theft. With its proactive monitoring, data-driven analytics, efficiency improvements, and cost-saving benefits, the system not only safeguards valuable fuel resources but also mitigates financial risks, fostering a more secure and resilient fuel management ecosystem. Through the integration of innovative technologies and collaborative efforts, stakeholders can confidently tackle the pressing issue of fuel theft, paving the way for sustainable growth and security in the fuel industry.

REFERENCES

1. Huang, H., Xiao, S., Meng, X., and Xiong, Y., "A Remote Home Security System Based on Wireless Sensor Network and GSM Technology", Proceedings of Second International Conference on Networks Security, Wireless Communications and Trusted Computing, 2010.
2. Katkar, G., Lanke, S., Kumar, A., and Khawate, S., "Fuel Checker and Theft Detection", IJARIIE, Vol. 9, No. 3, 2017, pp. 1813-1815.
3. Nagaraja, B.G., Ravi Rayappa, M. Mahesh, Chandrasekhar M. Patil, Manjunath, T.C., "Design & Development of a GSM Based Vehicle Theft Control System", 978-0-7695-3516-6/08 ©2008 IEEE, DOI 26 10.1109/ICACC.2009.154, pp.148-15.
4. Rilwano, R., "Sistem pengukuran konsumsi bahan bakar pada sepeda motor berbasis arduino". Diploma Thesis, Universitas Andalas, Padang, 2016.
5. Sharma, A., Sharma, P., Bhardwaj, D., Mishra, D., and Soni, A., "Load Cell Based Fuel Theft Detection System Journal of Electronics and Communication Systems", MAT Journals, Vol. 3, No. 1, 2016, pp. 1-4
6. Al-Majeed, Salah, et al. "Smart system for oil theft detection and localization." 2015 IEEE International Conference on Industrial Technology (ICIT). IEEE, 2015.
7. Parreira, Bernardo, et al. "An IoT-Based Approach for Gas Leakage Detection and Notification in Urban Areas." Sensors 20.8 (2020): 2193.
8. Arora, Aditi, and Pradeep Tomar. "IoT-Based Real-Time Fuel Monitoring System for Automobiles." 2020 International Conference on Emerging Smart Computing and Informatics (ESCI). IEEE, 2020.
9. Babu, Sujana, Sujatha M., and Thota Prasad. "A real- time fuel theft detection and monitoring system using IoT." 2019 4th International Conference on Communication and Electronics Systems (ICCES). IEEE, 2019.
10. Bhattacharyya, Sandip, et al. "A Comprehensive Survey on IoT-Based Oil and Gas Industry: Challenges, Opportunities, and Future Directions." IEEE Access 9 (2021): 665-686

Sentiment Analysis of Pandemic Tweets using Combination of Lexicon and Supervised Machine Learning based Approaches

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ABSTRACT

Pandemic creates a challenging circumstance in different sectors such as education, health, transportation, finance, supply chain, etc. This led to people developing different opinions about those ever-changing situations and they can use various social media platforms to express their emotions. Sentiment analysis is a process of detecting sentiments such as positive, negative and neutral from an unstructured textual data. It is extremely crucial as it helps the Government and businesses to quickly understand people feelings, reactions and make accurate executive decisions based on it. The main objective of this work is to extract the sentiments of people developed during the crucial period from their social media handles. It can be achieved with the help of various machine learning (ML) algorithms by training the model using labelled dataset of a particular topic of interest and testing the model how accurately it predicts the sentiment of new dataset of similar topic. To do so, it is required to collect pandemic related tweets from twitter, labelled them using the unsupervised learning mechanism (Lexicon approach) and develop a model to predict the sentiment of unlabeled data related to pandemic. Here, the combination of Lexicon based approach and ML based approach such as Decision Tree, K-Nearest Neighbor (KNN), Naive Bayes to classify tweet sentiments using KNIME Analytics Tool. Results show that Decision Tree provides better performance with 86.07% accuracy than other standard models.

KEYWORDS: *Tweets, Pandemic, Sentiment analysis, Machine Learning, Lexicon approach, Accuracy.*

INTRODUCTION

Pandemic is a highly widespread infectious disease all over the world such as COVID-19, Ebola, etc. This disease spreads at an alarming rate across the globe affecting almost every country. Due to these types of disease outbreak, whole world went into a period of lockdown over a large period of time affecting people's livelihood. Meanwhile people started developing mixed feelings towards the pandemic and expressed their views on various social media platforms such as Facebook, Twitter, etc. [1].

The extraction of sentiment out of unseen tweets from the social media has become a hot theme for the current scenario [2, 3]. The regulating bodies of a country require the information to know the current state of a region and control the situation. The researchers have been working on it since this topic has arisen and they have changed the way of analyzing the data. The tweets from twitter are generally used for sentiment analysis. Twitter platform has more active users than any other blogs, events etc. It is the largest opinion sharing platform. 280 characters limit restriction in tweets has even made it more precise as a person will have

to share short and to the point information, eradicating unnecessary details [4]. Hashtags, mentions are most important features in twitter to extract information related to a particular topic. Hashtags are used to particularly indicate the subject or genre of the tweet, like #COVID19 indicates tweets related to COVID19. A person with similar kind of views to another person can retweet his/her tweet without even writing it completely [5]. At the same time, it has its own demerits as people start using abbreviations and informal languages that include emoticons, various unknown expressions, etc. This creates a problem for the model in analyzing the proper sentiment of a tweet.

Text analysis has earned a major importance in business, political, geographical and social areas. It has become much easier for those bodies to interact with people directly using social media. Nowadays, public is much reliable on the social media such as Twitter, Facebook, Instagram, etc. for any information [6]. They express their moods, opinions about society and their regular activities on these social media. Social media has become a platform for companies to promote their products. Similarly, users also share their reviews, experience about a product on the same. This creates a large amount of data to perform a certain type of analysis [7].

The main focus of this work is to design a hybrid ML model that can be used to predict the impact of coronavirus on people life by eradicating the sentiment of people during this pandemic by analyzing their comments on social media platform such as Twitter. Here, tweets related to hashtag #COVID19 are gathered manually using the Twitter API. Those tweets are then labelled using dictionary tagging and term frequency features, and are used to find the accuracy of various ML algorithms.

The contributions of this work are stated as follows.

- Classifying the tweets into positive, negative, neutral using ML approach.
- Pandemic related tweets specific to COVID-19 were taken from Twitter using the Twitter API.
- 10000 recent tweets using hashtag #COVID19 are collected and performed sentiment analysis on these tweets.
- This work is carried out using KNIME Analytics Tool.
- Decision Tree model performs better as compared to other model.
- In Decision Tree, 86.07% accuracy on an average can be achieved with 61% negative sentiment, 25.46% positive sentiment and 13.54% neutral sentiments. In KNN, 81.65% accuracy can be achieved with 75.49% negative sentiment, 15.05% positive sentiment and 9.46% neutral sentiments. Naive Bayes classifier provides 59.04% accuracy.

The rest of the paper is organized as follows. Section 2 shows related works, Section 3 shows the methodology, and Section 4 describes the results. The conclusion of the work is discussed in Section 5.

RELATED WORKS

Many works have been carried out related to sentiment analysis [1-33]. Some of the works are described as follows. Dandannavar et al. [8] have examined the various steps involved in sentiment analysis of twitter data using various ML algorithms. Those steps include collection of data, preprocessing, feature extraction, and finally classification. Aloufi et al. [9] have performed a sentiment analysis on football related tweets using various ML algorithms. They prepared a dataset which comprised of labelled tweets related to football to train the model and predict further sentiments of new data. Elbagir et al. [10] being inspired by the topic ordinal regression, have performed a deep analysis on tweets to predict the sentiment using various ML algorithms. Decision tree have performed well in their case in comparison to other ML algorithms. Alamoodi et al. [11] have performed a sentiment analysis on the occurrence of various types of infectious diseases in the last decade. Barkur et al. [12] have done a sentiment analysis of people in India towards lockdown using hashtags #IndiaLockdown and #IndiafightsCorona. A word-cloud was generated to predict the sentiment of tweets using R software. Heras-Pedrosa et al. [13] have examined the effect of social media in misinterpreting the communication of risk and how it has affected the emotions and sentiments of Spanish people during the COVID-19 pandemic. Alatas et al. [14] have done a analysis on twitter data using KNIME analytics tool.

By implementing ML algorithms, the accuracy of prediction is calculated. Sahayak et al. [15] have done a sentiment analysis on twitter data related to a particular product or service. They collected twitter data and labelled them and trained a model so that it can estimate the sentiment of future unlabeled tweets. Pokharel et al. [16] have focused on analyzing the sentiment of people of a particular region (Nepal) and in a certain time period that is 21st MAY 2020 to 31st MAY 2020 related to the COVID-19 pandemic. Xue et al. [17] have proposed a ML model to predict the psychology and thinking of people during the COVID19 pandemic. They used twitter platform to extract tweets related to COVID-19. Rajput et al. [18] have performed an analysis on tweets related to COVID-19 using two approach based on word frequency and sentiment analysis of individual tweets. Tianyi Wang et al. [19] have used unsupervised BERT to predict the sentiment of tweets and TF-IDF to extract the topic of related posts.

METHODOLOGY

In this work, a ML based model has proposed which is the combination of Lexicon and ML approach. By using the Lexicon approach, the tweets that are collected from twitter using twitter API are labeled by performing preprocessing and thereafter implementing the concept of dictionary tagging. The output (labeled tweets) of the Lexicon approach is then feed to the ML model to check the accuracy and further the accuracy of model is checked after scoring and visualization is done. The model architecture is described in Fig. 1.

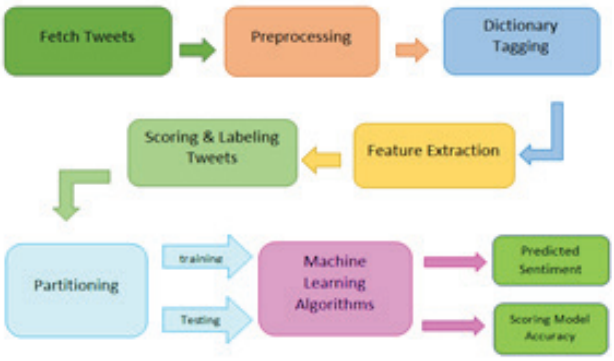

Fig. 1 Model architecture

The lexicon approach is described in Fig. 2 and the lexicon approach KNIME workflow is mentioned in Fig. 3. Here, the Twitter search is performed using Twitter API connector. Then, row/column filter operation is performed. Then preprocessing is done and afterwards dictionary tagging followed by mathematical operation. Finally, labelled data is generated.

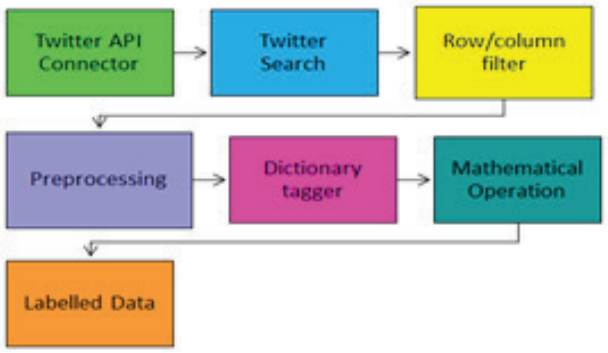

Fig. 2. Lexicon approach

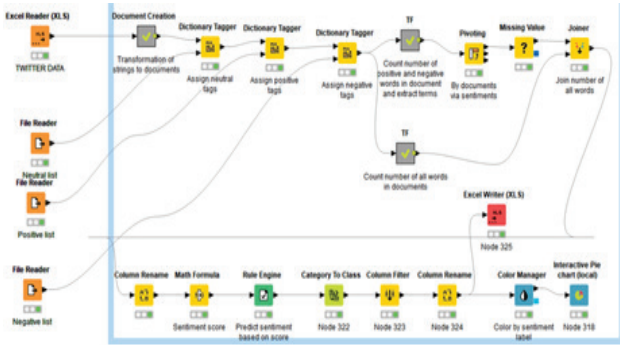

Fig. 3. KNIME workflow

The ML approach is described in Fig. 4 and the lexicon approach KNIME workflow is mentioned in Fig. 5. Here, the text processing is done on labeled tweets and then feature extraction is performed. Then partitioning is performed. Afterwards, training and testing is performed to generate the results.

Fig. 4.ML approach

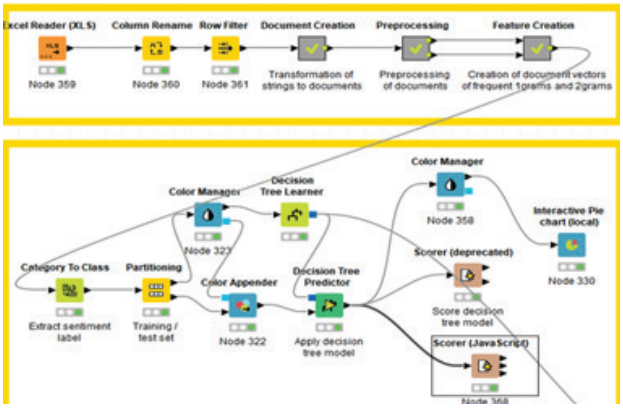

Fig. 5. ML approach KNIME workflow

Here, 10000 tweets related to hashtag #COVID19 from twitter using the Twitter API is collected. To use the twitter API, it is required to have a twitter developer account. Now, the collected data are converted into documents for further use and are filtered to avoid duplication. Special symbols, URLs, numerical values, punctuation and retweets are removed. After performing all the above operations in the preprocessing stage, a clean filtered set of data will be generated. This clean data is then fed to Lexicon approach for labelling the tweets using the dictionary tagging, term frequency and mathematical functions. After the tweets are labelled in this approach, it is given as an input to the ML model so that the model performance can be checked. Unlike Lexicon approach, ML uses feature extraction process using n-gram feature, which increases the accuracy of the model. The labelled tweets are then partitioned into training and testing set with varying proportion. The training and testing set are then fed to different ML algorithms to check the prediction accuracy of different algorithms. In this work, Decision Tree, KNN and Naïve Bayes models [20-24] are focused.

RESULTS AND DISCUSSION

In this work, KNIME Analytics Platform Tool is used for evaluating the results. Here, computer specification needed to run the tool efficiently are Windows 10 Operating System, Intel core-i5 8th Generation, 32/64 bit Operation System and 6GB RAM. Here, each node of KNIME workflow has its configuration settings by default. It is required to change the setting in the partitioning node where the proportion of training and testing data is set (Training 70% and Testing 30%). Here, it is observed that, tweets that are correctly classified is 1538, wrongly classified is 249. The performance of Decision tree algorithm with 70% training data and 30% gives an overall accuracy of 86.07 % with error of 13.934% and Cohen's kappa (k) of 0.748. Cohen's kappa (k) is the quantitative measure of the relativity between two rather rating the same thing. Higher value of Cohen's kappa means the algorithm has performed well with high efficiency. The value of k ranges from 0 to 1. The analysis result is mentioned in Fig. 6.

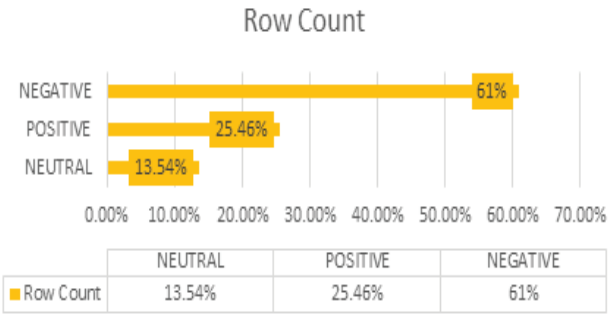

Fig. 6: Analysis using Decision tree (Training-70%, Testing-30%)

Here, it is observed that, tweets that are correctly classified is 1459, wrongly classified is 328. The performance of KNN algorithm with 70% training data and 30% testing data gives an overall accuracy of 81.645 % with an error of 18.355 % and Cohen's kappa (k) of 0.633. The analysis result is mentioned in Fig. 7.

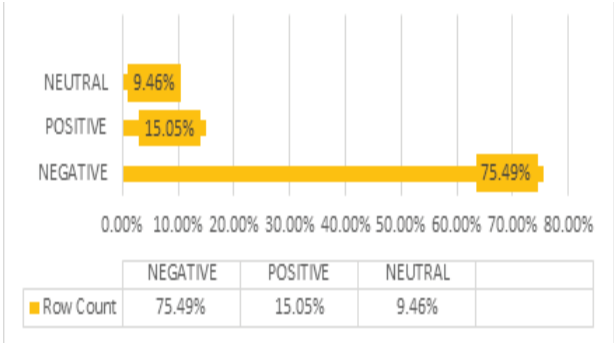

Fig. 7. Analysis using KNN (Training-70%, Testing-30%)

Here, tweets that are correctly classified is 1055, wrongly classified is 732. The performance of Naïve Bayes algorithm with 70% training data and 30% testing data gives an overall accuracy of 59.037 % with an error of 40.963 % and Cohen's kappa (k) value of 0. The analysis result is mentioned in Fig. 8.

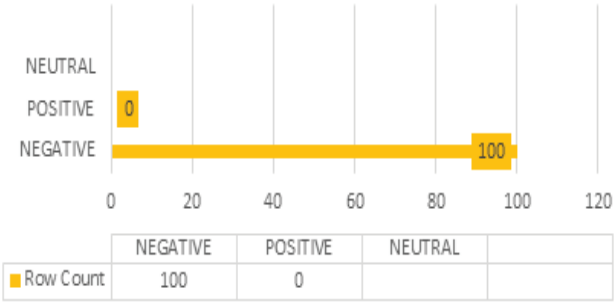

Fig. 8. Analysis using Naïve Bayes (Training-70%, Testing-30%)

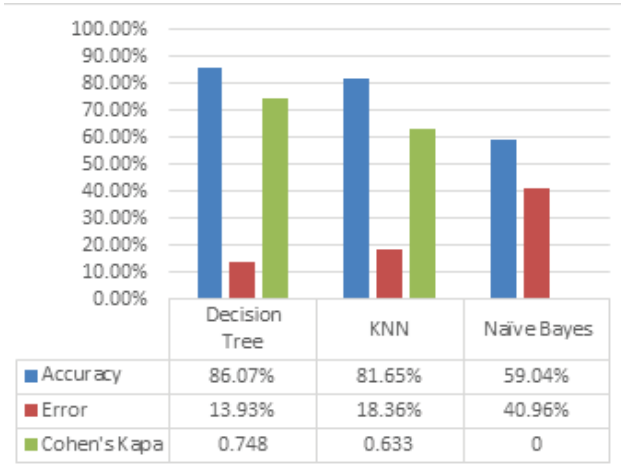

Fig. 9 Comparison results of different models (Training-70%, Testing-30%)

Fig. 9 show the comparison results of Decision Tree, KNN and Naïve Bayes models at (Training-70%, Testing-30%). From the results, it is observed that, in (Training-70%, Testing-30%) scenario, the Decision Tree model is able to provide 86.07%, 13.93% and 0.748 accuracy, error and Cohen's Kappa values respectively. The KNN model is able to provide 81.65%, 18.36% and 0.633 accuracy, error and Cohen's Kappa values respectively. The Naïve Bayes model is able to provide 59.04%, 40.96% and 0 accuracy, error and Cohen's Kappa values respectively. From the above analysis, it is observed that, Decision Tree model is able to provide better performance as compared to KNN and Naïve Bayes models.

CONCLUSION

In this work, a ML based approach is proposed for the analysis of sentiment of people from Twitter data. This work is focused on the ML based models such as Decision Tree, KNN and Naïve Bayes. In this work, 10,000 tweets are taken with #COVID-19 hashtags manually from Twitter Public Database using Twitter API Connector. From the results, it is concluded that, the Decision Tree model is performs better as compared to KNN and Naïve Bayes models with an accuracy of 86.07%. This work can be extended to create an interface that can better visualize and interact with the users. An improved approach can be performed to enhance the performance.

REFERENCES

1. Pang, Bo, and Lillian Lee. "Opinion mining and sentiment analysis." Foundations and Trends® in Information Retrieval 2, no. 1–2 (2008): 1-135.
2. O'Connor, Brendan, Ramnath Balasubramanyan, Bryan R. Routledge, and Noah A. Smith. "From tweets to polls: Linking text sentiment to public opinion time series." In Fourth international AAAI conference on weblogs and social media. 2010.
3. Cabanlit, Mark Anthony, and Kurt Junshean Espinosa. "Optimizing N-gram based text feature selection in sentiment analysis for commercial products in Twitter through polarity lexicons." In IISA 2014, The 5th International Conference on Information, Intelligence, Systems and Applications, pp. 94-97. IEEE, 2014
4. Saif, Hassan, Miriam Fernandez, Yulan He, and Harith Alani. "Evaluation datasets for Twitter sentiment analysis: a survey and a new dataset, the STS-Gold." (2013).
5. Murthy, D., 2018. Twitter. Cambridge, UK: Polity Press.
6. Graham, G. and Meriton, R., 2016, October. Sentiment analysis using KNIME: a systematic literature review of big data logistics. In Proceedings of the Eighth International Conference on Emerging Networks and Systems Intelligence (pp. 96-99). International Academy, Research, and Industry Association.
7. Bernard, H.R. and Ryan, G., 1998. Text analysis. Handbook of methods in cultural anthropology, 613.
8. Jain, Anuja P., and Padma Dandannavar. "Application of machine learning techniques to sentiment analysis." In 2016 2nd International Conference on Applied and Theoretical Computing and Communication Technology (iCATccT), pp. 628-632. IEEE, 2016

9. Aloufi, Samah, and Abdulmotaleb El Saddik. "Sentiment identification in football-specific tweets." IEEE Access 6 (2018): 78609-78621

10. Saad, Shihab Elbagir, and Jing Yang. "Twitter Sentiment Analysis Based on Ordinal Regression." IEEE Access 7 (2019): 163677163685

11. Alamoodi A, Zaidan B, Zaidan A, Albahri O, Mohammed K, Malik R, Almahdi E, Chyad M, Tareq Z, Albahri A, Hameed H. Sentiment analysis and its applications in fighting COVID-19 and infectious diseases: A systematic review. Expert systems with applications. 2020 Oct 28:114155

12. Barkur, Gopalkrishna, and Giridhar B. Kamath Vibha. "Sentiment analysis of nationwide lockdown due to COVID 19 outbreak: Evidence from India." Asian journal of psychiatry (2020).

13. de Las Heras-Pedrosa, Carlos, Pablo Sánchez-Núñez, and José Ignacio Peláez. "Sentiment analysis and emotion understanding during the COVID-19 pandemic in spain and its impact on digital ecosystems." International Journal of Environmental Research and Public Health 17.15 (2020): 5542.

14. Baydogan, C. and Alatas, B., 2018, March. Sentiment analysis using Konstanz Information Miner in social networks. In 2018 6th International Symposium on Digital Forensic and Security (ISDFS) (pp. 1-5). IEEE..

15. Sahayak, V., Shete, V. and Pathan, A., 2015. Sentiment analysis on twitter data. International Journal of Innovative Research in Advanced Engineering (IJIRAE), 2(1), pp.178-183.

16. Pokharel, B.P., 2020. Twitter sentiment analysis during COVID-19 outbreak in nepal. Available at SSRN 3624719.

17. Xue, J., Chen, J., Chen, C., Zheng, C., Li, S. and Zhu, T., 2020. Public discourse and sentiment during the COVID 19 pandemic: Using Latent Dirichlet Allocation for topic modeling on Twitter. PloS one, 15(9), p.e0239441.

18. Rajput, N.K., Grover, B.A. and Rathi, V.K., 2020. Word frequency and sentiment analysis of twitter messages during Coronavirus pandemic. arXiv preprint arXiv:2004.03925.

19. Wang, T., Lu, K., Chow, K.P. and Zhu, Q., 2020. COVID-19 Sensing: Negative sentiment analysis on social media in China via Bert Model. Ieee Access, 8, pp.138162-138169.

20. Rokach, Lior & Maimon, Oded. (2005). Decision Trees. 10.1007/0-387-25465-X_9.

21. Jotheeswaran, Jeevanandam. (2013). Opinion mining using decision tree based feature selection through Manhattan hierarchical cluster measure. Journal of Theoretical and Applied Information Technology. 58. 72-80.

22. Cunningham, Padraig & Delany, Sarah. (2007). k-Nearest neighbour classifiers. Mult Classif Syst.

23. Rezwanul, Mohammad & Ali, Ahmad & Rahman, Anika. (2017). Sentiment Analysis on Twitter Data using KNN. International Journal of Advanced Computer Science and Applications. 8. 10.14569/IJACSA.2017.080603.

24. Dey, Lopamudra & Chakraborty, Sanjay & Biswas, Anuraag & Bose, Beepa & Tiwari, Sweta. (2016). Sentiment Analysis of Review Datasets Using Naïve Bayes' and K-NN Classifier. International Journal of Information Engineering and Electronic Business. 8. 54-62. 10.5815/ijieeb.2016.04.07

25. Rakshit, P., Sarkar, P., Ghosh, D., Roy, S., Talukder, S., & Chakraborty, P. S. (2023). Sentiment Analysis of Twitter Data Using Deep Learning. In Advances in Communication, Devices and Networking (pp. 495-501). Springer, Singapore.

26. Biradar, S. H., Gorabal, J. V., & Gupta, G. (2022). Machine learning tool for exploring sentiment analysis on twitter data. Materials Today: Proceedings, 56, 1927-1934.

27. Singh, C., Imam, T., Wibowo, S., & Grandhi, S. (2022). A Deep Learning Approach for Sentiment Analysis of COVID-19 Reviews. Applied Sciences, 12(8), 3709.

28. Jalil, Z., Abbasi, A., Javed, A. R., Badruddin Khan, M., Abul Hasanat, M. H., Malik, K. M., & Saudagar, A. K. J. (2022). Covid-19 related sentiment analysis using state-of-the-art machine learning and deep learning techniques. Frontiers in Public Health, 9, 2276.

29. AlBadani, B., Shi, R., & Dong, J. (2022). A novel machine learning approach for sentiment analysis on Twitter incorporating the universal language model fine-tuning and SVM. Applied System Innovation, 5(1), 13.

30. Rodrigues, A. P., Fernandes, R., Shetty, A., Lakshmanna, K., & Shafi, R. M. (2022). Real-time twitter spam detection and sentiment analysis using machine

learning and deep learning techniques. Computational Intelligence and Neuroscience, 2022.

31. Babu, N. V., & Kanaga, E. (2022). Sentiment analysis in social media data for depression detection using artificial intelligence: A review. SN Computer Science, 3(1), 1-20.

32. Jain, R., Bawa, S., & Sharma, S. (2022). Sentiment Analysis of COVID-19 Tweets by Machine Learning and Deep Learning Classifiers. In Advances in Data and Information Sciences (pp. 329-339). Springer, Singapore.

33. Gulati, K., Kumar, S. S., Boddu, R. S. K., Sarvakar, K., Sharma, D. K., & Nomani, M. Z. M. (2022). Comparative analysis of machine learning-based classification models using sentiment classification of tweets related to COVID-19 pandemic. Materials Today: Proceedings, 51, 38-41.

IoT-Based Wireless EV Charging System for Electric Vehicle

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ABSTRACT

Electric cars (EVs) have been hailed for their social benefits by the auto industry, but wireless charging offers even more potential. An intelligent infrastructure is required for EV charging because traditional cable charging systems have problems with scalability, safety risks, and physical connection limits. A unique method of wireless EV charging uses the principles of inductive power transfer (IPT) to overcome these obstacles. The technology, which consists of three essential parts—the EV, charging station, and power supply unit—revolutionizes EV charging. The charging station's inbuilt power coils transmit a high-frequency AC signal that the power supply unit creates from grid-supplied AC electricity. Efficient power transfer to the EV is ensured by ground-based receiving coils, and smooth communication and control are made possible by IoT capabilities. To improve compatibility with EV systems, the power is converted to DC upon reception using a voltage regulator and rectifier. Real-time monitoring of energy use, battery health, and charging status is made possible by incorporated IoT technologies in the EV. By enabling intelligent charging patterns, load balancing, and demand response, this data maximizes energy efficiency and reduces grid stress. This wireless EV charging system combines IoT and IPT technologies to provide optimal efficiency, versatility, and user-friendliness. In addition to encouraging widespread EV use and reducing environmental effect, it signals a revolutionary move towards sustainable transportation infrastructure. As more people adopt greener energy options, wireless charging becomes apparent as a key component of the electric mobility revolution, with the potential to completely change the car industry going forward.

KEYWORDS: *Wireless power transmission, Inductive power transfer, IoT, EV.*

INTRODUCTION

Transportation with automobiles has been around for a while. Internal combustion engines power these cars. As the number of cars rises, internal combustion engines (IC engines) contribute to environmental pollution and a decrease in the use of fossil fuels. Fuel efficiency and emissions are being reduced by new developments in the vehicle sector. Hybrid vehicles cut emissions while maintaining engine performance by combining internal combustion engines and electric motors. Clean, green energy that emits no emissions will be prioritized in the future. The development and production of electric vehicles have attracted a lot of industry attention. Batteries have three main drawbacks: they are expensive, have a short range, and require a long time to charge. Customers are constantly looking for ways to make travel more efficient. Consequently, all gas stations now have charging systems that are connected. The limitations of wired charging include things like socket locations, distance between charging stations, limited cable lengths, and the requirement to move the car in order to connect to the charger. Electric car wireless charging options can aid in resolving these problems. Systems may be installed anywhere, including residences, parking lots, and garages, and this enables flexible and hassle-free charging. Because they don't require wires or physical contact, Wireless Power Transfer (WPT) systems—especially those that use Wireless Inductive Power Transfer (IPT)—offer a number of benefits, including increased reliability, ease of use, safety, and lower maintenance costs.

These benefits make WPT systems appropriate for use in a variety of industries, including biomedical implants, textiles, space technology, mobile phones, and military

applications. They are also appropriate for use in electric cars. It becomes vital in this situation to consider the idea of a wireless charger made especially for electric cars. In order to minimize stress on the electrical grid, this type of charger would use electromagnetic induction for connection and functioning. Nikola Tesla originally proposed inductive power transfer—which does not require a magnetic core—nearly a century ago with the intention of wirelessly transferring mains power across great distances. Ever since, medical equipment has found use for low-powered, closely connected wireless charging, and commercial goods that allow portable gadgets to be charged wirelessly using charging mats frequently available.

Systems for wireless inductive power transfer are generally divided into two groups according to their range: systems that are medium to long range and can be used in personal area networks, and systems that are short range and usually cover a distance of approximately 5 inches. The main area of interest for this research is intermediate wireless transfer capability. The focus of this study is on inductive coupling with matched resonance frequency, which highlights important aspects of effective wireless power transfer such as coil quality factor, resonance frequency alignment, link efficiency, and impedance matching. Non-radiative magnetic coupling is also investigated as a way to lower energy consumption and increase the suitability of WPT systems for medium-to long distance transmission.

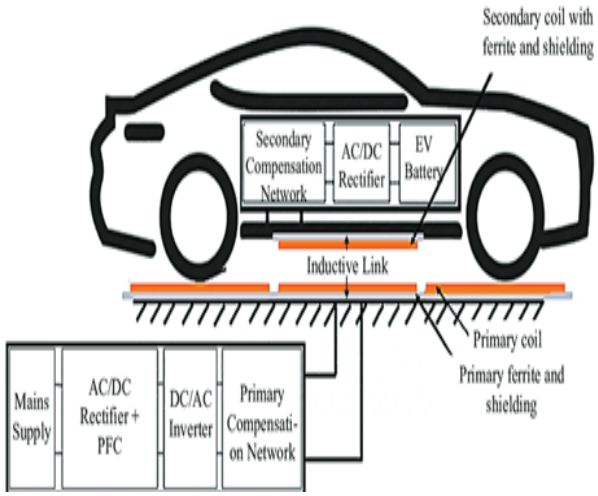

Fig 1. System prototype for wireless charging

Table1: Methods of Wireless Power

Methods	Advantages	Negative elements
Coupling inductive	Easy, secure, and very effective transfer over short distances.	For short transmission distances, precise alignment is required.
Coupling of magnetic resonance	extended transmission range and radiation-free	adjusting the resonance frequency for various devices is difficult
Radiation from electromagnetic field	extremely high long-range transmission efficiency	extremely high long-range transmission efficiency.

METHODOLOGY

The technology of wireless charging is one that is growing quickly and has attracted a lot of attention lately. Monitoring the charging process to guarantee effective and secure charging is one of the difficulties with wireless charging. The ESP32 module is a well-liked option for tracking wireless charging stations due to its low power consumption and wireless capabilities. We go over some of the most current research on ESP32-based wireless charging station monitoring in this overview of the literature. Research indicates that using the ESP32 module as a foundation for monitoring wireless charging stations is dependable and effective. To guarantee effective and secure charging, The user can receive feedback, collect data, and monitor in real time with the ESP32 module. Further research is necessary in order to optimize the functionality and performance of ESP32-based wireless charging stations and explore the variety of potential applications for them.

Block diagram [2] of an IoT-Based Wireless Vehicle Charging Station delineates the interconnected system components and their collaborative functioning. At the core of this setup lies the ESP32 Microcontroller, serving as the central control unit. This controller manages diverse operations such as communication with the app control interface, coordination of the charging process, interaction with various sensors and detectors, and implementation of power-saving measures. The charging

system comprises Dual Spot Charging, facilitating the simultaneous wireless charging of two electric vehicles. This process is enabled through Inductive Power Coils, ensuring efficient energy transfer. The MOSFET (IRZ44N) regulates and controls the power flow, ensuring the safety and efficiency of the charging process. Interfacing with the app control interface, users can seamlessly manage and monitor the charging process via a mobile application. Commands initiated through the app interface are processed by the ESP32 controller, enabling actions like initiating or ceasing the charging process. Sensors and detectors integrated into the system include an IR Sensor responsible for vehicle detection and positioning, enabling automated charging when a vehicle is parked over the charging spot. The Auto Detection System identifies electric vehicles and triggers the initiation of the charging process automatically upon detection. Additionally, the system incorporates voltage regulation using a Voltage Regulator (7805) for stable voltage supply and energy-saving components to optimize power consumption. A Storage Battery (Lead Acid) acts as a backup power source, ensuring uninterrupted service in case of power failure or emergencies. Display functionalities are facilitated by a 16x2 LCD Display, providing real-time visual feedback on the charging status. Together, these components and their collaborative functioning, orchestrated by the ESP32 controller, create a robust and efficient wireless charging infrastructure for electric vehicles, focusing on user convenience, safety, and energy efficiency.

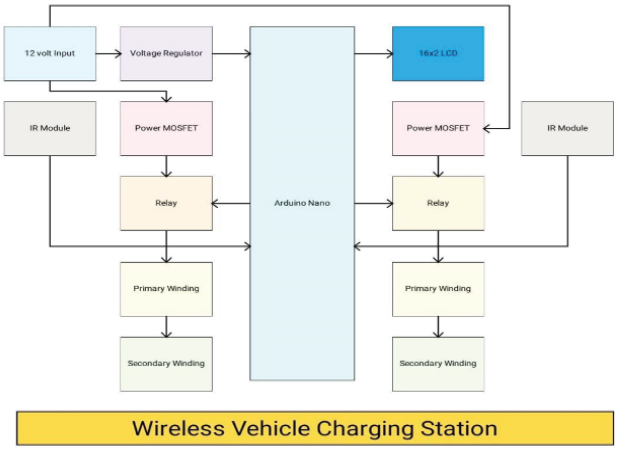

Fig. 2. Proposed System's Block Diagram

WIRELESS CHARGING SYSTEM ARCHITECTURE

Figure 3 illustrates the charging system, which includes many components. An alternating current (AC) supply is utilized to deliver high voltage.

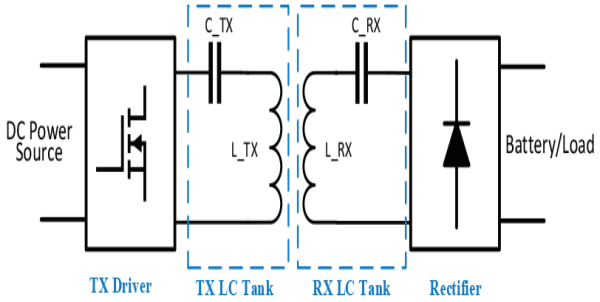

Fig. 3: Circuit Model

Low frequencies are converted to high frequencies using a frequency converter (HF). The transmission coil (TX) is attached to this output. Resonant coupling is used to connect the receiving coil (RX). An AC-DC converter is used to convert the output to rectified DC, which is then utilized to charge the battery, which acts as the load. The coils used in the wireless power transmission project are called magnetic resonators. A fast-oscillating current is first fed to a coil at a specific resonance frequency using an HF converter. A reception coil should be tuned to the same resonant frequency as the source in order to produce a magnetic field surrounding a transmission coil. In doing so, the coupled magnetic response—an electrical current inside the receiving coil—will be coupled with the resonant magnetic field. A load can receive power in order to charge batteries. It is possible to divide this electricity across several loads.

The WPT system's basic circuit model, which is connected in a series-to-series topology, is shown in Figure 3. Considering the complexity of the system, evaluating the simplified equivalent network model is simple. L1 and L2, the circuit's primary and secondary windings, respectively. On the primary side, we have R1, C1, and on the secondary side, R2, C2. The elements are passive and linear in character. The resonance of an RLC circuit is a feature. It is possible to adjust the LC values to get a resonant frequency between 10 and 30 kHz. The input voltage V1 and the total impedance of the secondary coil as seen by the primary determine

the current flowing through the primary coil I1. The circuit's total impedance, or Ztotal, is determined by

$$Ztotal=Requiv+j(XL-XC) \quad (1)$$

$$Requiv=R1+R2 \quad (2)$$

$$XL = \omega 0(L1+L2) \quad (3)$$

$$XC = \frac{1}{\omega 0}(C1+C2) \quad (4)$$

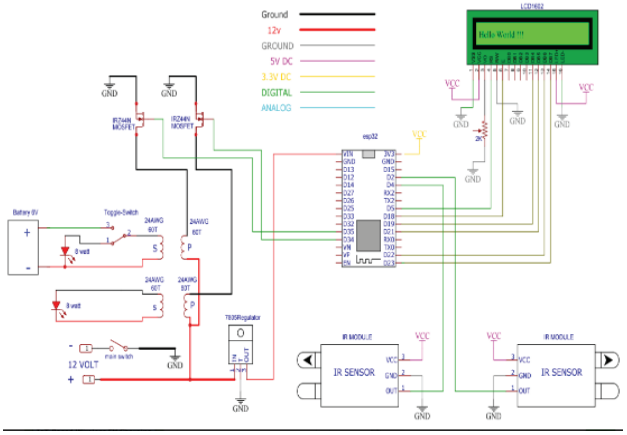

Fig 4: Schematic Diagram

An electric vehicle charging system's circuit diagram is displayed in Figure 3.2. The microcontroller, the central component of the system, regulates the operations of the linked devices in accordance with the specifications. Embedded C programming is used to create the suggested system using the Arduino Uno processor. The system's various sensors are depicted in the figure. A current sensor measures the current flowing through a wire and outputs a signal that is directly proportional to the current. An ammeter is used to display the measured current using the output signal, which can also be used for additional analysis. Another crucial sensor is the voltage sensor, which is primarily employed to translate observed voltage into a physically represented signal that is directly proportional to voltage. The measurement result is output by connection V, a physical signal port. Its unique feature is its ability to detect voltage levels without requiring metal-to-metal contact. Its components, which are embedded in a casted resin with a very low inductance, are resistive voltage dividers and integrated resistors. Together with the resin permittivity, which functions as a capacitance, the entire arrangement has a zigzag shape.

Node MCU, OLED, and Arduino Uno. The Microchip ATmega328P microcontroller, on which the Arduino Uno microcontroller board is based, includes analog and digital input/output pins that may be connected to a variety of expansion boards and circuits.

SOFTWARE SPECIFICATIONS

Arduino IDE:

Specifications:

IDE for Legacy (1.8.X) - IDE for Arduino (1.8.19).

Blynk App:

Specifications:

Blynk IOT App- Version:2.27.34

Blynk is a versatile mobile application designed to simplify the process of creating IoT (Internet of Things) projects by enabling users to control and monitor connected devices remotely.

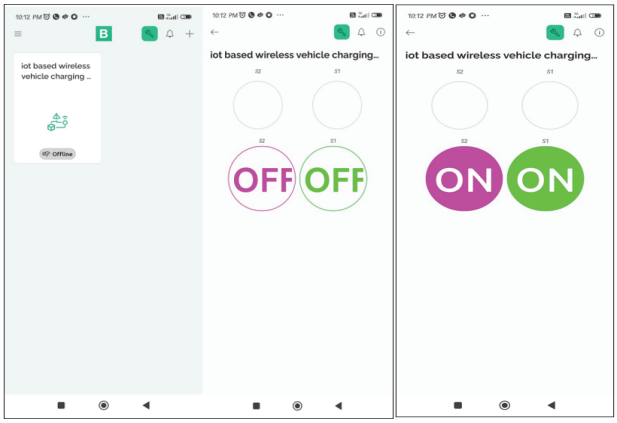

Fig 5: App Implementation Screenshots

SYSTEM FLOW

Step 1: Set Up Blynk Account and Project

Step 2: Install Blynk Library in Arduino IDE

Step 3: Hardware Connection:

Step 4: Write Arduino Sketch:

Step 5: Define Blynk Authentication Token:

Step 6: Set Up Virtual Pins:

Step 7: Write Code for Interfacing with Blynk App:

Step 8: Test Communication with Blynk App

Step 9: Debug and Refinement:

Step 10: Documentation and Deployment:

CONCLUSION

In conclusion, wireless charging eliminates the need for bulky wires and plug points, making it a straightforward and cutting-edge way to charge electric cars (EVs). demonstrating the effectiveness and usefulness of this technology, when the EV is parked above the wireless charger, electricity is created in the coil located at the bottom of the vehicle by mutual induction. Additionally, the expansion of wireless charging to allow charging while driving signifies a substantial development in EV charging capabilities, offering users increased convenience and flexibility. With implications for the future of transportation infrastructure, this evolution highlights the ongoing innovation in the field of wireless power transfer.

This is the envisions future technologies like RFID tag payment and self-service entry and exit gates, highlighting the potential of wireless charging systems to change EV charging stations. The aforementioned enhancements are intended to optimize workflow, reduce traffic, and improve the overall user experience at charging stations. All things considered, the investigation of wireless charging technology in this work makes a significant addition to the area by providing insights into its effectiveness, use, and possible future advancements. As wireless charging develops further, it has the potential to completely disrupt not just the transportation sector but also a number of other industries, such as consumer electronics, healthcare, and industrial automation, thereby establishing itself as a game-change technological advancement.

FUTURE WORK

Dynamic charging solutions that are high-performing, safe, and reasonably priced will be at the vanguard of the electric vehicle (EV) revolution, which has the potential to completely change road transportation in the future. Finding the best mix of capacitive and inductive. Wireless Power Transfer (WPT) technologies is essential to this evolution and offers huge research opportunities in near-field coupler design and high-frequency power electronics. Additional research should be done in a few crucial areas: The long-term health effects of being exposed to weak electric and magnetic fields produced by dynamic charging devices require more research in order to ensure the safety of both users and onlookers. To guarantee public safety and prevent mishaps, it is crucial to have strong systems for identifying live things and foreign items near WPT systems. To maximize the advantages of dynamic charging infrastructure, performance and cost-effectiveness must be optimized. This requires methods to identify the most efficient charger power levels and spacing. The development of methods for smoothly integrating WPT technology into traffic will be essential for its broad adoption and for making it possible for EVs to be conveniently charged while traveling.

REFERENCES

1. K.A. Kalwar, M. Aamir, S. Mekhilef, "Inductively coupled power transfer (ICPT) for electric vehicle charging – A review", Renewable Sustainable Energy Reviews, Vol. 47, pp. 462-475, July 2015.
2. H. Barth, M. Jung, M. Braun, B. Schmülling, U. Reker, "Concept Evaluation of an Inductive Charging System for Electric Vehicles", Presented at the 3rd European Conference Smart Grids and E-Mobility, Munchen, Germany, 2011
3. M. SangCheol, K. Bong-Chul, C. Shin-Young, A. Chi-Hyung, M. Gun Woo, "Analysis and design of a wireless power transfer system with an intermediate coil for high efficiency", IEEE Transactions on Industrial Electronics, Vol. 61, Issue 11, pp. 5861-5870, 2014.
4. J. Wu, B. Wang, W. S. Yerazunis, K. H. Teo, "Wireless power transfer with artificial magnetic conductors" Proceedings IEEE Wireless Power Transfer Conference, Perugia, Italy, pp. 155-158, 2013
5. Ronak Ramesh Sancheti, Chetan Shivaji Kurkute, Prasad Sanjay Karmalkar, Aryan Gupte, Dr. Preeti Patil, "Iot-Based Wireless EV Charging System For Electric Vehicle Using Inductive Power Coils." International Journal of Current Science (IJCSPUB), Vol. 13, Issue 2, May 2023.
6. P. Paul, P. Mohanty, S. S. Mahapatra, and D. K. Pradhan, "Design of Wireless Charging Station for Electric Vehicles using ESP32 with IoT-Based Monitoring System," 7th International Conference on Advanced Computing and Communication Systems (ICACCS), Coimbatore, India, pp. 57-62, 2021.

7. D. Mandal, S. Singh, S. Biswas, S. Roy, S. S. Saha, and S. K. Ray, "Design and Implementation of a Multi-Device Wireless Charging Station Using ESP32," 6th International Conference on Control, Automation and Robotics (ICCAR), Nagoya, Japan, pp. 385-390, 2021.

8. S. Obayashi, Y. Kanekiyo and T. Shijo, "UAV/Drone Fast Wireless Charging FRP Frustum Port for 85-kHz 50-V 10-A Inductive Power Transfer", IEEE Wireless Power Transfer Conference (WPTC), pp. 219-222, 2020.

Food Industry Analytics and Forecasting: Utilising Time Series Models for Improved Decision-Making

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ABSTRACT

In today's world, Accurate demand forecasting is crucial for the food industry to optimise production, inventory, and pricing. This research investigates the application of Facebook Prophet, a powerful time series forecasting model, in this domain. Prophet's ability to capture seasonality, trends, and holidays aligns perfectly with the dynamic nature of food demand. We demonstrate its application using a real-world food-related dataset (e.g., daily or monthly sales data), analyse its performance metrics, and interpret the results to provide actionable insights for food industry professionals. Furthermore, we explore the integration of anomaly detection techniques to identify unexpected fluctuations in demand, potentially caused by external factors or emerging trends.

KEYWORDS: *Time series analysis, FB Prophet, ARIMA, Food industry, Anomaly detection, Food optimisation.*

INTRODUCTION

Time series analysis is crucial for identifying and predicting patterns in sequential data, impacting sectors like finance, economics, and meteorology. Key models such as ARIMA (AutoRegressive Integrated Moving Average) and SARIMA (Seasonal ARIMA) are well-regarded for their proficiency in capturing non-seasonal and seasonal fluctuations in time series data, making them essential for analysts across various fields. ARIMA and SARIMA provide a robust framework incorporating autoregression and moving averages, enhanced by SARIMA's ability to handle recurring seasonal effects, thus extending their applicability.

Nonetheless, traditional models like ARIMA and SARIMA may struggle with the complexities of modern datasets, which often exhibit nonlinear patterns, irregular seasonality, and significant outliers. In response, FB Prophet, developed by Facebook's Core Data Science team, offers a compelling alternative for time series forecasting. This open-source tool, accessible to both experts and novices, automatically identifies change points and accounts for holidays and events—factors often missed by traditional models [1].

This paper analyses ARIMA, SARIMA, and FB Prophet, concentrating on their utility and effectiveness in forecasting time series. Supported by empirical evaluations and detailed case studies, the paper seeks to uncover insights that can guide researchers and practitioners in time series analysis and forecasting. By examining their theoretical and practical uses, this study aims to align theoretical knowledge with real-world applications [2].

The paper explores time series analysis and forecasting techniques deeply, offering insights into their foundational theories and practical implementations. It evaluates each method's advantages and disadvantages, addressing their reliability and accuracy in various scenarios and highlighting potential challenges. The study illustrates each method's performance by comparing different datasets, helping practitioners choose the most effective approach based on specific datasets and conditions[3].

The analysis provides strategic guidance for implementing time series analysis and forecasting in real-world scenarios, ensuring technique selection is informed by thorough empirical evidence.

LITERATURE REVIEW

This research examines various time series models, such as BATS, TBATS, Holt's Linear Trend, ARIMA, and NNAR, to forecast milk production in Turkey using data from 1991-2019. The lowest Mean Absolute Percentage Error (MAPE) during 2015-2019 tests identified ARIMA models as best for Culture purebred and Indigenous milk production, TBATS for Crossbreed production, and Holt's for total. It predicts a 25% increase in total production by 2025 [4].

Another study compares ARIMA and ETS models for wheat production forecasting in India using data from 1956-2020. ARIMA models performed better in Uttar Pradesh and Punjab while ETS models were more accurate in Madhya Pradesh, Haryana, Rajasthan, and India overall. Wheat production is expected to rise, especially in Madhya Pradesh [5].

The author proposes a hybrid ARIMA-ANN model for time series forecasting, combining ARIMA's linear strengths and ANN for non-linear patterns, using gold prices to demonstrate improved accuracy over standalone models [6]. Time series analysis with ARIMA is applied to predict agricultural food production, stressing its importance in developing economies and suggesting neural networks as a more effective alternative due to ARIMA's limitations [7].

Historic research on forecasting agricultural production, such as ARIMA application by Balanagammal et al. (2000) for Tamil Nadu, and foundations by Box et al. (1994, 2007), underscore ARIMA's utility in forecasting trends, specifically in Odisha for food grain production [8]. For India's food grain production and productivity, ARIMA, ARNN, and hybrid ARIMA-ARNN models are compared, finding ARNN most accurate for predicting growth to 2025-26, highlighting time series models' role in agricultural policy [9].

METHODOLOGY

In this analysis, we present the results and key findings derived from our time series analysis. We explored various methods including ARIMA, SARIMA, and FB Prophet on the dataset. Notably, our in-depth investigation primarily focused on leveraging the FB Prophet library.

Data Collection and Preparation:

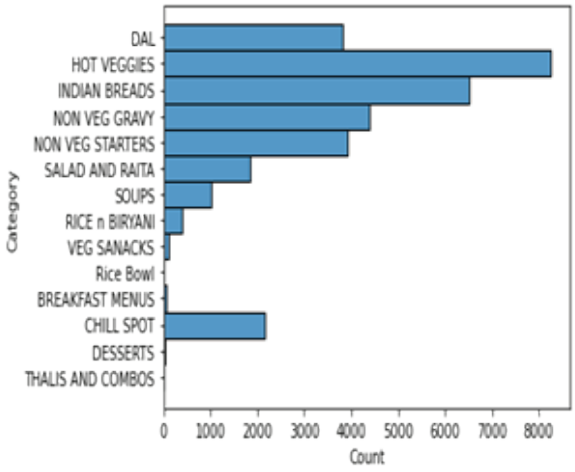

Fig. 1: Food categories from the dataset.

Our research meticulously collected a substantial dataset of over 33,000 food order records from a credible source over the period from 2021 to 2023, providing a comprehensive view of customer preferences within the food industry. To preserve data integrity throughout the analysis process, rigorous pre-processing steps were executed, addressing missing values, removing or adjusting outliers, and ensuring consistent formatting. Specifically, missing data was imputed with appropriate values, outliers were handled diligently, and any inconsistencies in formatting were standardised to produce a cohesive dataset. As shown in Fig. 1 the key categories like Hot Vegetables, Indian Breads, Non-Vegetarian Gravy, and Dal were picked due to they have high sales and are highly popular with customers. In data preprocessing, managing null values was a critical aspect of model implementation, given their potential to significantly undermine prediction model accuracy. A backward-filling technique was employed to address missing entries by filling them with the last available valid data for each category. The Prophet model was developed using the Augmented Dickey-Fuller (ADF) test to assess the stationarity of time series data. The ADF test ensures that the data is consistent in mean and variance, allowing for accurate forecasting. The Prophet

model was preprocessed to consider holidays and seasonal patterns, enhancing performance. Controlled experiments were conducted to optimise model accuracy and capture customer dining behaviors. The dataset was divided into training and testing subsets for robust model development and evaluation. If non-stationarity was detected, a differencing approach was introduced to trace sequential variations. The test_stationarity function was applied to ensure the data was suitable for the Prophet model, achieving a stationary format.

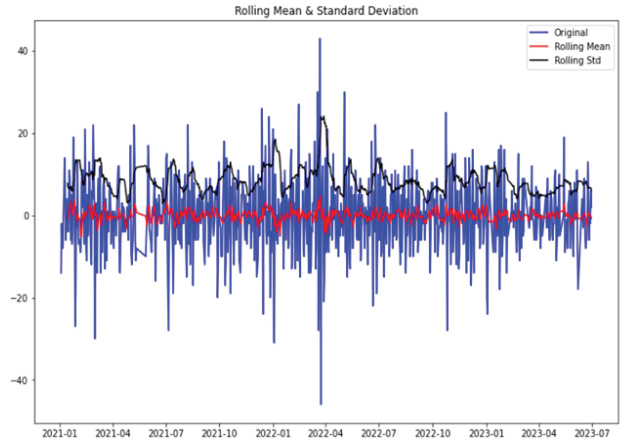

Fig. 2: Calculated rolling mean and standard deviation.

Opting to decompose a time series for further analysis is a discretionary step that follows the process of differencing Fig. 2, which may have already addressed data non-stationarity. Nonetheless, delving into decomposition allows a more in-depth exploration of the time series, particularly through seasonal decomposition, which enables us to visually and analytically segregate the underlying trends, seasonal patterns, and residual noise in sales data. Within Statsmodels, the seasonal_ decompose function from the statsmodels.tsa.seasonal module is utilised to achieve this decomposition. This function effectively dissects a time series into its constituent trend, seasonal, and residual elements.

We applied the function to the differenced sales data, specifying a 365-day period to consider possible yearly seasonality typical in restaurant sales. This decomposition process yields three key components: the trend, which reflects the long-term trajectory of sales data; the seasonal component, capturing fluctuations possibly attributed to events like holidays or weather changes; and the residuals, highlighting noise or unexplained variance after factoring out trend and seasonality. With Matplotlib's subplot plotting, we constructed a four-panel display where each panel graphically presents one of the components alongside the original differenced data, enabling clear comparison and facilitating the identification of distinct patterns in sales data.

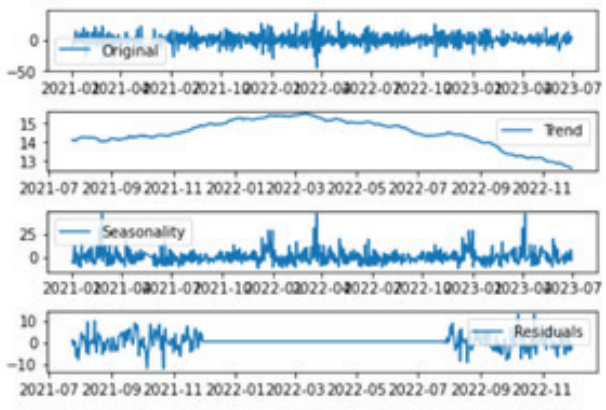

Fig. 3: Plotting the trends, seasonality, and residuals in food quantity of category.

The Prophet model analyses residuals, which are data unexplained by trend or seasonal components Fig. 3, to ensure optimal model performance. Stationarity is crucial for optimal results. Post-cleaning, residuals' stationarity is assessed using the test_stationarity function. Autocorrelation Function and Partial Autocorrelation Function plots help identify appropriate parameters for the Prophet model.

Model Implementation

The research utilised ARIMA, SARIMAX, and Facebook Prophet libraries in Python to analysis restaurant sales trends. However, due to data limitations, ARIMA and SARIMA were not suitable. Instead, Prophet was used for time series forecasting, specifically for restaurant sales. The model was optimised by tuning parameters, considering holidays and sales seasonality. Prophet's ability to manage multiple time series allowed for unique models for four food categories, predicting future food quantities. This method aids in inventory and menu planning based on expected demand.

The Prophet model's forecasting ability is detailed for four food categories: Non-veg gravy, Indian bread, Daal, and Hot veggies. Each subplot in Fig. 4 illustrates

the actual quantities, shown by scattered black dots, against the predicted figures represented by a blue line which highlights the trend and seasonality with a shaded confidence interval. Non-veg gravy maintains a steady trend with periodic variations due to seasons, reflecting the model's predictive prowess. Indian breads showcase marked seasonality, with the model accurately capturing annual peaks and troughs. Daal consumption trends show minor seasonal deviations, demonstrating a strong model fit and consumer demand stability. Meanwhile, the Hot Veggies category reveals dynamic patterns and a possible upward trend. While capturing the general trends, the model shows some discrepancies, indicating complex consumer preferences. Analysing these insights assists businesses in understanding consumer behavior and improving strategic planning.

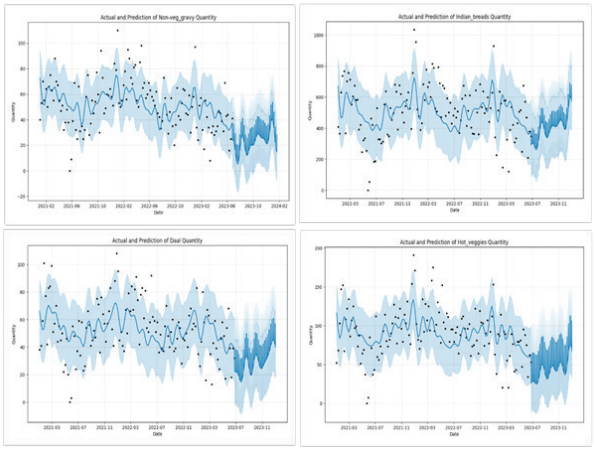

Fig. 4: Forecasting the quantity based on selected categories

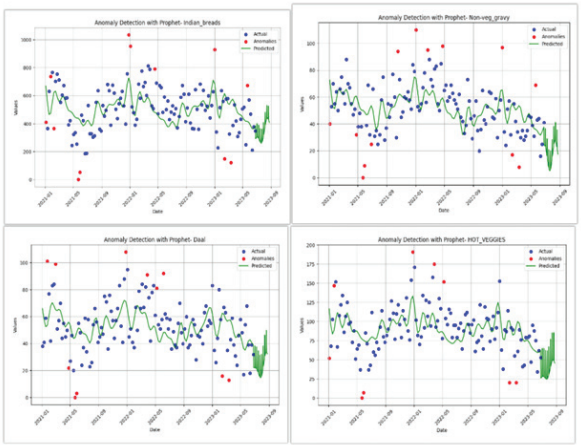

Fig. 5: Plotting anomaly detection

Fig. 5 presents four graphs using the Prophet model for anomaly detection in food categories: Indian bread, Non-veg gravy, Daal, and HOT VEGGIES. The x-axis shows dates, while the y-axis displays values. Actual values are marked by blue dots, predicted values by a green line, and anomalies by red dots. These graphs illustrate the Prophet model's skill in identifying trends and seasonality; the green line closely follows the blue dots, highlighting discrepancies with red dots for further analysis.

RESULTS

Prophet's performance in forecasting was compared with ARIMA and SARIMA models, though these models did not fit well, leading to the application of Prophet. The performance was evaluated using Mean Absolute Error (MAE) as a metric.

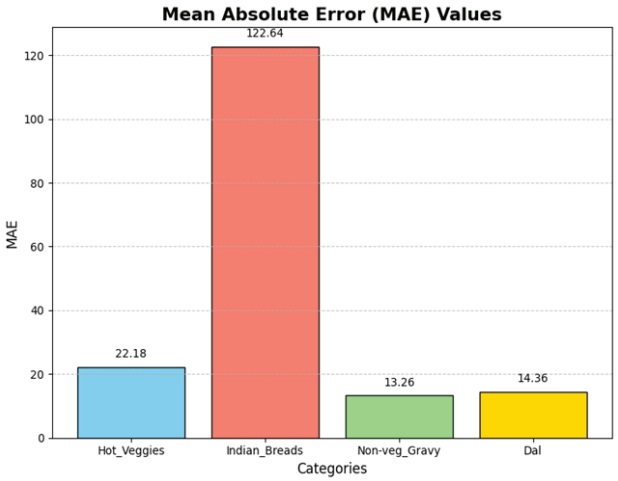

Fig. 6: Evaluation of selected food categories.

The MAE values for predictions in Fig. 6 present four Indian cuisine categories: Hot_Veggies, Indian_Bread, Non-veg_Gravy, and Dal. The figure shows disparity in MAE among categories. Indian_Bread has the highest MAE at 122.64, indicating the lowest prediction accuracy. Conversely, Non-veg_Gravy and Dal have lower MAEs of 13.26 and 14.36, suggesting better performance by Prophet in these areas. Hot_Veggies has an intermediate MAE of 22.18. Distinct colors represent each category: sky blue for Hot_Veggies, salmon pink for Indian_Bread, light green for Non-veg_Gravy, and gold for Dal. The x-axis labels the categories, y-axis indicates MAE, and grid lines assist in interpreting

MAE values. "Mean Absolute Error (MAE)" values provide clarity to the data presented.

Model Performance Visualisation

We present time series plots and forecasts generated by Prophet and other models, visually comparing their fit to the actual data. Evaluation Metrics Comparison: Fig.6 the performance metrics for each category, allowing for a quantitative comparison. We discuss Prophet's strengths, such as its ability to capture seasonality and trends effectively, and its interpretability. We also acknowledge limitations, such as potential challenges with highly irregular data or unexpected events.

CONCLUSION

This research examined the potential of time series analysis and Facebook Prophet to enhance demand forecasting in the food industry. By thoroughly collecting and processing data, we gained insights into customer preferences and demand trends. Our results show that Prophet is effective in forecasting food demand, adeptly handling seasonality, trends, and holidays. The model, assessed through metrics like Mean Absolute Error, accurately predicts sales across various categories. Visualisations further confirm Prophet's capability to capture customer behavior and identify anomalies. Despite its strengths, Prophet does have limitations, especially with irregular data or unexpected events that disrupt patterns.

Thus, choosing a forecasting model should depend on the data's characteristics and context. This research highlights time series forecasting's potential in optimising operations and improving customer satisfaction within the food industry. Prophet offers a strong framework for understanding and predicting demand, ultimately enabling businesses to make informed, efficient decisions.

REFERENCES

1. Majhi, S. K., Bano, R., Srichandan, S. K., Acharya, B., Al-Rasheed, A., Alqahtani, M. S., ... & Soufiene, B. O. (2023). Food price index prediction using time series models: A study of Cereals, Millets and Pulses.
2. Barbosa, N. D. P., Christo, E. D. S., & Costa, K. A. (2015). Demand forecasting for production planning in a food company. ARPN Journal of Engineering and Applied Sciences, 10(16), 7137-7141.
3. Yonar, H., Yonar, A. Y. N. U. R., Mishra, P., Abotaleb, M., Al Khatib, A. M. G., Makarovskikh, T. A. T. I. A. N. A., & Cam, M. U. S. T. A. F. A. (2022). Modeling and forecasting of milk production in different breeds in Turkey. Indian J. Anim. Sci, 92(1), 105-111.
4. Shrivastri, S., Alakkari, K. M., Lal, P., Yonar, A., & Yadav, S. (2022). A Comparative Study between (ARIMA—ETS) Models to Forecast Wheat Production and its Importance's in Nutritional Security. Journal of Agriculture, Biology and Applied Statistics1 (1), 25-37.
5. Fawzy, H., Rady, E. H. A., & Fattah, A. M. A. (2021). Forecasting time series using a hybrid ARIMA-ANN methodology. J. Appl. Probab. Stat, 16, 95-106.
6. Kumar, A. P., & Bhramaramba, R. (2017). Time series data analysis on agriculture food production. Advanced Science and Technology Letters (SMART DSC-2017), 147, 520-525.
7. Dash, A., Dhakre, D. S., & Bhattacharya, D. (2017). Forecasting of food grain production in Odisha by fitting ARIMA model. Journal of pharmacognosy and phytochemistry, 6(6), 1126-1132.
8. Dheer, P. (2019). Time series modelling for forecasting of food grain production and productivity of India. Journal of Pharmacognosy and Phytochemistry, 8(3), 476-482.
9. Deshmukh, S. S., & Paramasivam, R. (2016). Forecasting of milk production in India with ARIMA and VAR time series models. Asian Journal of Dairy and Food Research, 35(1), 17-22.

Summarizing Audio Conversations using Abstractive Summarization Approaches

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ABSTRACT

In the era of digital communication, audio conversations, particularly in the form of calls, have become ubiquitous. With the increasing reliance on virtual meetings, there is a growing need for tools capable of summarizing conversations and providing users with efficient post-meeting insights. This paper explores the abstractive approach to summarizing text along with the development and implementation of a tool, focusing on its integration into communication platforms. The approach involves a multi-step process to enable real-time summarization. First, the tool extracts and decodes audio packets from each user in the conversation. Next, a real-time transcription mechanism converts spoken words into text. This summarization process leverages the Facebook BART (Bidirectional and Auto-Regressive Transformers) for abstractive summarization. Our approach leverages the Vosk model for real-time speech-to-text transcription, achieving a Word Error Rate (WER) of 36.12%. The fine-tuned Facebook BART (Bidirectional and Auto-Regressive Transformers) model is evaluated using ROUGE metrics. On the SAMSUM conversation dataset, the fine-tuned BART model achieves strong ROUGE scores (ROUGE-1: 54.138, ROUGE-2: 26.154, ROUGE-L: 41.543, ROGUE-LSUM 39.324) which is 18.65% better than popularly used BART(XSUM) model. By fine-tuning BART to adapt to summarizing dialog based content, we aim to create a tool that provides a free and offline solution that meets the current demands of users.

KEYWORDS: *Speech-to-text, Text-summarization, Extractive summarization, Abstractive summarization, Model-based summarization*

INTRODUCTION

In the current landscape of virtual meetings and remote collaboration, the demand for efficient communication tools has never been higher. While platforms like Microsoft Teams have made strides in offering transcription services, their reliance on post-event transcripts falls short when it comes to delivering real-time, contextually relevant summaries.

This paper seeks to address this limitation by proposing a practical approach to real-time conversational summarization, capitalizing on the opportunities presented by open-source communication platforms like Discord. Discord, known for its developer-friendly environment, stands out for its comprehensive API documentation, accommodating various programming languages. This paper explores the possibility of developing a tool in the form of a bot that can actively

participate in voice conversations within Discord channels, extracting audio data from users in real-time. Discord's API facilitates the integration of third-party applications, allowing for innovative solutions that go beyond the traditional constraints of closed systems.

This paper focuses on creating a bot that not only accepts audio data from users in a Discord voice channel but also employs straightforward processes to generate textual summaries. This tool aims to bridge the gap between spoken conversations and actionable insights without unnecessary embellishments. We delve into the technical aspects of our approach, covering the extraction and decoding of audio packets, real-time transcription, and abstractive summarization using the Facebook BART model, presenting a pragmatic solution to enhance communication experiences in virtual environments.

Looking ahead, the future scope of our project includes expanding functionality to accommodate user preferences, such as language options for conversation summarization. This enhancement would allow users to choose the language of the conversation being held, promoting inclusivity and adaptability in diverse communication scenarios. By taking a practical and user-centered approach, our project aims to contribute valuable insights and advancements to the ongoing discourse on communication tools, ensuring they remain relevant and user-friendly in the evolving landscape of virtual collaboration.

LITERATURE SURVEY

HetTreeSum, a novel methodology rooted in tree-based structures, specifically designed for extractive summarization tasks focused on scientific papers. This approach utilizes dependency trees to meticulously traverse the syntactic structure of documents, thereby facilitating syntactic coherence and selective information extraction. By leveraging the inherent syntactic relationships encoded in the tree structures, HetTreeSum effectively captures key phrases, words, or clauses crucial for conveying the core meaning of the source text [1].

However, despite its proficiency in maintaining syntactic coherence and extracting selective information, HetTreeSum encounters challenges in content abstraction. In particular, when applied to dialogues, which often involve nuanced exchanges and multifaceted conversations, HetTreeSum may struggle to abstract and capture the underlying meaning effectively, potentially resulting in summaries that fail to encapsulate the richness of the conversation. Furthermore, the method's reliance on clear syntactic structures may limit its effectiveness in processing dialogues characterized by informal language or domain-specific jargon, where such structures may be less evident or absent altogether.

Template-based models for summarizing legal texts operate by employing predefined templates to generate summaries, ensuring high coherence and relevance to the source content. Leveraging these templates, the models excel in structuring summaries and selecting pertinent information from the source text. However, they face challenges in abstraction and flexibility, particularly when applied to dialogues characterized by dynamic conversational flows and diverse linguistic styles. Designing effective templates for summarizing dialogues requires a deep understanding of conversational dynamics and the ability to anticipate different scenarios, which can be challenging and may result in oversimplification or inadequacy in capturing the richness of the conversations. Additionally, the adaptability of template-based models to informal conversations or unconventional dialogue structures remains limited, potentially leading to incomplete or inadequate summaries in such contexts [2].

Rule-based text summarization methods, which rely on predefined linguistic rules, patterns, and heuristics to generate summaries. These methods provide a high level of control over the summarization process and can be customized to suit specific domains or document types. However, the dynamic nature of dialogues makes creating and maintaining comprehensive summarization rules time-consuming and labor-intensive. Constant updates are needed to keep pace with evolving language use, potentially hindering the practicality of rule-based methods in capturing nuanced interactions effectively [3].

Semantic graph-based models for single-document summarization, which construct a semantic graph, often referred to as the Rich Semantic Graph (RSG),

from the source document. The RSG represents the document's content by capturing relationships between entities, concepts, and important terms, enabling structured content extraction and content abstraction [4]. However, despite their strengths, these models encounter challenges in handling dialogue-specific nuances and constructing accurate graphs for diverse conversational styles, potentially limiting their applicability in summarizing dialogues effectively.

BART, a Transformer-based model tailored for text summarization tasks. BART exhibits strong performance in text generation and comprehension tasks, making it suitable for summarizing dialogues effectively [6]. Despite its abstractive summarization prowess and flexibility in handling diverse linguistic styles, BART may encounter challenges in accurately capturing dialogue-specific nuances, such as conversational markers and informal language, which are crucial for generating contextually relevant summaries. Additionally, the computational resources required for training and fine-tuning BART models may pose limitations, particularly for dialogue datasets with large volumes of data, potentially hindering its scalability. Further research and adaptation are necessary to address domain and language-specific challenges and optimize BART's performance for dialogue summarization tasks.

MATERIALS AND METHODS

Following steps taken to develop and implement the real-time conversational summarization tool within the Discord platform as shown in Figure 1. The approach encompasses the extraction and processing of audio data, real-time transcription, and abstractive summarization using the Facebook BART, a Seq-to-Seq model which generates output sequences based on input sequences, often used for tasks like translation and summarization which is better than traditional cascading systems which are prone to error between components [13, 14].

A Platform Selection and Setup

We leveraged Discord's comprehensive API documentation to integrate our summarization tool seamlessly. This involved setting up a bot user, obtaining API credentials, and establishing a connection to Discord channels. The Discord Developers Portal serves as a central hub for developers to access documentation, resources, and tools necessary for integrating third-party applications with Discord. It provides a wealth of information, including API references, guides, and community support forums.

Within the portal, developers can register a bot, obtaining essential credentials such as the bot token. This token is used to authenticate and connect the bot to Discord servers, enabling it to join voice channels, access messages, and perform other designated actions. Discord employs OAuth2, a widely-used authentication protocol, to allow secure interactions between applications and the Discord platform. Developers can configure OAuth2 settings for their applications through the portal, defining the scopes and permissions required for the bot to function effectively.

Node.js TypeScript Application

The backend application utilizes the Discord API to communicate with the Discord platform and control the registered bot. This integration involves handling various API endpoints, such as voice channel interactions, message processing, and bot status updates. The application houses the control logic that governs the behavior of the bot within Discord channels. This includes the implementation of real-time audio data extraction, processing, and the integration of the summarization model. Node.js, known for its non-blocking I/O and event-driven architecture, is employed to handle asynchronous operations and events triggered by user interactions within Discord channels.

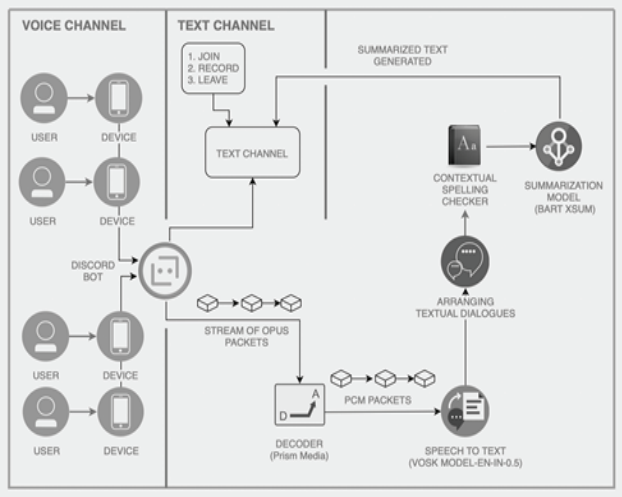

Fig 1. Complete Summarization Process Diagram

Audio Data Extraction

Our approach involves extracting audio packets from each user in the voice channel. We utilized Discord's audio processing capabilities to efficiently capture and decode these packets as listed below:

- Stream Subscription and Opus Packets: In this step, our backend application utilizes the Dscord API to subscribe to a stream provided for each user in the voice channel. Discord's API facilitates the streaming of audio data in the form of Opus packets, which is a widely used audio codec in real-time communication applications. Each user's audio stream represents a continuous flow of Opus-encoded audio data.
- Using RxJS Operators for Stream Handling: RxJS (Reactive Extensions for Javascript) operators are employed for handling the audio stream in a reactive and asynchronous manner. The 'subscribe' operator is utilized to listen to and consume the incoming stream of Opus packets from each user. This ensures that the backend application is notified whenever new audio data is available.
- Piping to Decoder with prism-media: The received Opus packets need to be decoded to a format that is understandable by subsequent stages of the processing pipeline. The 'pipe' operator from RxJS is employed to seamlessly transfer the Opus stream to a decoder provided by the prism-media npm library. The prism-media library supports audio processing and manipulation, and in this context, it includes a decoder capable of converting Opus-encoded audio to PCM (Pulse Code Modulation) format. PCM is a raw audio format that serves as an intermediary step before further processing. The 'pipe' operator efficiently connects the Opus stream to the decoder, allowing for continuous and real-time decoding.
- Compatibility with Vosk Speech-to-Text Model: The decoded PCM audio format is crucial for compatibility with the Vosk speech-to-text model. Vosk is an open-source, offline-capable automatic speech recognition (ASR) system. It requires audio input in PCM format to perform accurate transcription. By decoding the Opus packets into PCM format, our backend application ensures that the audio data is in a suitable format for the subsequent transcription stage. This compatibility enhances the efficiency and accuracy of the speech-to-text model, contributing to the overall effectiveness of the real-time conversational summarization tool.

Our approach to real-time transcription relies on the utilization of the Vosk model, an offline open-source speech recognition toolkit renowned for its versatilityn [5]. Vosk supports recognition for over 20 languages and dialects, including English, Indian English, German, French, Spanish, Chinese, Russian, and more. The toolkit's compact size (50 MB), continuous large vocabulary transcription, zero-latency streaming API response, reconfigurable vocabulary, and speaker identification make it an ideal choice for our real-time transcription needs. Following are the reasons for choosing this model -

The integration of the Vosk model in our project aligns with our goal of creating a versatile tool capable of functioning offline, ensuring continuous service in diverse network conditions. Recognized for its excellent performance in accurate and rapid speech recognition, Vosk meets the demands of dynamic and fast-paced.

Conversations for real-time transcription. Additionally, the compact size of Vosk models allows for efficient resource utilization, enabling deployment on various devices, from Raspberry Pi to larger clusters. In our real-time transcription process, each PCM packet decoded by the Prism Opus decoder is seamlessly fed into the Vosk model, ensuring a continuous and precise transcription of ongoing conversations. Abstractive Summarization: We employ the Facebook BART (Bidirectional and Auto-Regressive Transformers) model, which is a transformer-based model and has demonstrated remarkable capabilities in abstractive summarization tasks [6]. To tailor it for our specific use case, we fine-tuned the BART model using diverse datasets, including XSUM, SAMSUM, DIALOGSUM, and AMI using HuggingFace Transformers[7].

Dataset Description

- XSUM (Extreme Summarization): This dataset is designed for extreme summarization tasks, featuring short documents with single-sentence summaries [8]. The inclusion of XSUM in our fine-

tuning process ensures our model's proficiency in distilling essential information into concise summaries.

- SAMSUM Corpus: Leveraging the SAMSUM dataset enriches our model's ability to handle dialogues, as SAMSUM specifically focuses on conversations [9]. This contributes to the contextual understanding required for effective summarization in conversational scenarios.
- DIALOGSUM: The DIALOGSUM dataset provides dialogues that further augment the model's training on conversational structures [10]. This inclusion enhances the model's capacity to capture nuances and context within spoken exchanges.
- AMI (Augmented Multiparty Interaction): AMI is a dataset centered around multiparty meetings [11]. The incorporation of AMI data ensures that our model can navigate and summarize complex discussions typical of business meetings.

Among these summarization models TextRank Extractive, Sequence-to-sequence, Pointer-generator, and Lead-3, the seq-to-seq model, emerges as the optimal choice due to its ability to generate abstractive summaries with contextual understanding, overcoming limitations like out-of-vocabulary words and repetitive content [12,15]. Unlike extractive methods that merely select sentences, Bart synthesizes information, capturing the essence of the text comprehensively, making it the superior choice for summarization tasks. Fine-tuning the BART model for conversational summarization serves two crucial purposes. Firstly, it facilitates domain-specific adaptation by utilizing datasets that capture the nuances inherent in dialogues. This targeted approach ensures that the model becomes adept at summarizing conversations effectively, tailoring its capabilities to the intricacies of the spoken language. The diverse datasets expose the model to a wide array of contexts and the intricate relationships between utterances, enabling it to generalize better and perform optimally in various conversational scenarios.

By fine-tuning with datasets that span extreme summarization, dialogues, and multiparty interactions, we aim to enhance the model's abstractive summarization capabilities, allowing it to generate coherent and contextually rich summaries. The fine-tuned Facebook BART model is integrated into our abstractive summarization process. Once the real-time transcription is obtained from the Vosk model, the BART model processes the textual data to generate abstractive summaries. The amalgamation of fine-tuned BART with diverse datasets ensures that our model can effectively capture and distill the essence of spoken conversations, offering users concise and informative textual summaries of their dialogues.

RESULTS & DISCUSSION

Our implementation of the Vosk model for real-time transcription has demonstrated promising outcomes. Specifically, the model's Word Error Rate (WER) is recorded at 36.12. This WER value reflects a moderate level of accuracy in converting spoken language into text. While a WER of 36.12 indicates that there is room for improvement, it also represents a solid foundation upon which further refinements can be built. The relatively high WER suggests that the model can benefit from additional tuning and optimization to enhance its transcription accuracy.

In parallel, we have conducted an evaluation of our abstractive summarization approach using the fine-tuned Facebook BART model. The evaluation was performed using ROUGE metrics, which are standard measures for assessing the quality of generated summaries [6]. The results highlight the effectiveness of the fine-tuned BART model in generating summaries from text.

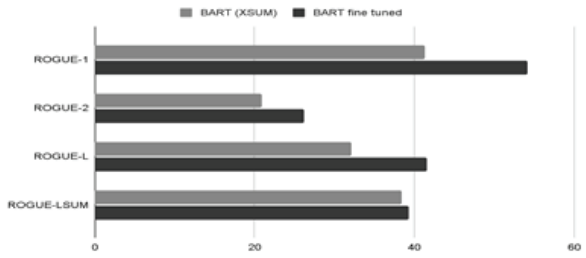

Fig. 2. Comparative analysis of BART (XSUM) and BART (fine-tuned)

For this evaluation, we utilized the SAMSUM dataset, which is specifically designed to capture conversational text. This dataset provides a more targeted assessment of summarization performance in dialogue contexts. The results from our fine-tuned BART model were

compared against a BART model trained on the XSUM dataset [8,9], which is more general and not specifically tailored for conversational data. The comparison is illustrated in Figure 2, which shows a graphical representation of the ROUGE scores for both models.

Table 1. Comparing Fine-tuned BART with BART XSUM

	BART (XSUM) [8]	BART (fine-tuned)
ROGUE-1	41.328	54.138
ROGUE-2	20.875	26.154
ROGUE-L	32.135	41.543
ROGUE-LSUM	38.401	39.324

We are exploring the possibility of fine-tuning models with user feedback for conducting detailed error analyses, identifying recurring patterns in transcription inaccuracies, and refining the Vosk model's language understanding. User feedback provides valuable information for fine-tuning parameters in the BART model, helping us address specific linguistic intricacies and contextual variations prevalent in different conversational scenarios. Continuous user feedback enables an adaptive learning approach, where the models can dynamically adjust to the evolving patterns and preferences of users over time. Ongoing iterations of model refinement, guided by user feedback, will be instrumental in reducing transcription errors, improving summarization accuracy, and addressing user-specific language nuances.

By incorporating user feedback into the model development pipeline, we aim to create a tool that not only meets the current demands of users but also evolves to become more adept at handling diverse linguistic contexts and user preferences. This user-centric approach ensures the continual improvement of our tool, making it a valuable asset for users engaging in voice conversations across various domains.

The results presented in Table 1 highlight the comparative performance of the fine-tuned BART model against the standard BART model trained on XSUM. The fine-tuned BART model exhibits superior performance across all ROUGE metrics:

- ROUGE-1: The fine-tuned model achieves a ROUGE-1 score of 54.138, which is significantly higher than the 41.328 score of the BART model trained on XSUM. ROUGE-1 measures the overlap of unigrams between the generated summary and reference summaries, indicating that the fine-tuned model captures more relevant terms.
- ROUGE-2: The fine-tuned BART model scores 26.154 in ROUGE-2, outperforming the 20.875 score of the XSUM model. ROUGE-2 evaluates the overlap of bigrams, reflecting the model's ability to maintain more complex word sequences.
- ROUGE-L: The fine-tuned BART model achieves a ROUGE-L score of 41.543 compared to 32.135 for the XSUM model. ROUGE-L measures the longest common subsequence, showing that the fine-tuned model better preserves the sequential structure of the text.
- ROUGE-LSUM: The fine-tuned model scores 39.324 in ROUGE-LSUM, which is slightly higher than the 38.401 score of the XSUM model. ROUGE-LSUM combines ROUGE-L with sentence-level evaluation, demonstrating the fine-tuned model's effectiveness in summarizing complete dialogues.

These improvements suggest that fine-tuning the BART model on the SAMSUM dataset, which focuses on conversations, significantly enhances its performance in generating coherent and relevant summaries for dialogue-based content.

CONCLUSION & FUTURE SCOPE

In conclusion, this paper addresses the growing need for real-time conversational summarization in virtual communication. By seamlessly integrating a robust tool within the Discord platform, capable of extracting, transcribing, and summarizing audio conversations, we aim to enhance the efficiency of digital collaboration. Our approach utilizes the Vosk model for real-time transcription, providing an offline solution that accurately converts spoken words into text. The fine-tuned Facebook BART model, incorporating datasets like XSUM, SAMSUM Corpus, DIALOGSUM, and AMI, demonstrates its ability to distill key information from diverse conversational contexts, generating contextually rich and concise summaries.

The paper's significance lies in its contribution to the evolution of communication tools, offering a versatile and accessible solution for popular platforms. As we look to the future, our exploration of user-selectable language options reflects a commitment to inclusivity and relevance in a global context. Despite encountered challenges, our iterative refinement process, guided by user feedback and performance evaluations, underscores our dedication to continuous improvement. In conclusion, our real-time conversational summarization tool not only addresses immediate demands but also lays the foundation for future innovations in contextual information extraction from spoken interactions.

REFERENCES

1. Zhao J, Yang L, Cai X. HetTreeSum: A Heterogeneous Tree Structure-based Extractive Summarization Model for Scientific Papers. Expert Systems with Applications. 2022 Dec;210:118335. Available from: http://dx.doi.org/10.1016/j.eswa.2022.118335
2. Dixit U, Gupta S, Yadav AK, Yadav D. Analyzing the Impact of Extractive Summarization Techniques on Legal Text. Lecture Notes in Networks and Systems. 2024; 585–602. Available from: http://dx.doi.org/10.1007/978-981-99-6544-1_44
3. Aote S, Pimpalshende A, Potnurwar A. Multi-Document Extractive Text Summarizer for Hindi Documents Using Swarm Intelligence Based Hybrid Approach. SSRN Electronic Journal. 2022; Available from: http://dx.doi.org/10.2139/ssrn.4019476
4. Joshi M, Wang H, McClean S. Dense Semantic Graph and Its Application in Single Document Summarisation. Studies in Computational Intelligence. 2017 Oct 31;55–67. Available from: http://dx.doi.org/10.1007/978-3-319-68392-8_4
5. Nickolay Shmyrev. Kaldi Gigaspeech Vosk Model. 2022. Alpha Cephei. https://alphacephei.com/nsh/ (accessed on Sept. 14, 2023)
6. Lewis M, Liu Y, Goyal N, Ghazvininejad M, Mohamed A, Levy O, et al. BART: Denoising Sequence-to-Sequence Pre-training for Natural Language Generation, Translation, and Comprehension. Proceedings of the 58th Annual Meeting of the Association for Computational Linguistics. 2020; Available from: http://dx.doi.org/10.18653/v1/2020.acl-main.703

[7] Ontoum S, Chan JH. Automatic Text Summaration of COVID-19 Scientific Research Topics Using Pre-trained Model from HuggingFace®. 2021 Dec 29; Available from: http://dx.doi.org/10.36227/techrxiv.17693702

[8] Narayan S, Cohen SB, Lapata M. Don't Give Me the Details, Just the Summary! Topic-Aware Convolutional Neural Networks for Extreme Summarization. Proceedings of the 2018 Conference on Empirical Methods in Natural Language Processing. 2018; Available from: http://dx.doi.org/10.18653/v1/d18-1206

[9] Gliwa B, Mochol I, Biesek M, Wawer A. SAMSum Corpus: A Human-annotated Dialogue Dataset for Abstractive Summarization. Proceedings of the 2nd Workshop on New Frontiers in Summarization. 2019; Available from: http://dx.doi.org/10.18653/v1/d19-5409

[10] Chen Y, Liu Y, Chen L, Zhang Y. DialogSum: A Real-Life Scenario Dialogue Summarization Dataset. Findings of the Association for Computational Linguistics: ACL-IJCNLP 2021. 2021; Available from: http://dx.doi.org/10.18653/v1/2021.findings-acl.449

[11] Renals S, Swietojanski P. Distant Speech Recognition Experiments Using the AMI Corpus. New Era for Robust Speech Recognition. 2017;355–68. Available from: http://dx.doi.org/10.1007/978-3-319-64680-0_16

[12] Nallapati R, Zhou B, dos Santos C, Gulcehre C, Xiang B. Abstractive Text Summarization using Sequence-to-sequence RNNs and Beyond. Proceedings of The 20th SIGNLL Conference on Computational Natural Language Learning. 2016; Available from: http://dx.doi.org/10.18653/v1/k16-1028

[13] See A, Liu PJ, Manning CD. Get To The Point: Summarization with Pointer-Generator Networks. Proceedings of the 55th Annual Meeting of the Association for Computational Linguistics (Volume 1: Long Papers). 2017; Available from: http://dx.doi.org/10.18653/v1/p17-1099

[14] Jia Y, Weiss RJ, Biadsy F, Macherey W, Johnson M, Chen Z, et al. Direct Speech-to-Speech Translation with a Sequence-to-Sequence Model. Interspeech 2019. 2019 Sep 15; Available from: http://dx.doi.org/10.21437/interspeech.2019-1951

[15] Jadeja D, Khetri A, Mittal A, Vishwakarma DK. Comparative Analysis of Transformer Models on WikiHow Dataset. 2022 International Conference on Sustainable Computing and Data Communication Systems (ICSCDS). 2022 Apr 7; Available from: http://dx.doi.org/10.1109/icscds53736.2022.9761043

An Intelligent Learning Approach for Cardiac Arrhythmia Classification Using Dilated Temporal Convolution Network with Spatial Attention Mechanism

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ABSTRACT

Arrhythmia is one type of cardiovascular disorder that affects human health. The smart Electrocardiogram (ECG) analysis is an efficient strategy for the accurate treatment and the timely prevention of arrhythmia. It is normal to view the multi-label criterion in the clinical waveforms that one individual can be labeled with numerous kinds of arrhythmia. Nevertheless, the present experiments highly employ multi-class techniques to resolve the issue of multi-label, ignoring the relationships among the disorders and producing data loss. In order to resolve these limitations, a deep learning-assisted arrhythmia classification model is introduced. At first, the input ECG signals are gathered from benchmark sites. Further, the wave features and spectral features are retrieved from the signals. This feature extraction process helps to obtain prominent information for arrhythmia classification. Further, the arrhythmia classification is performed via the developed Dilated Temporal Convolution Network with Spatial Attention mechanism (DTCN-SA). This classification helps to precisely identify irregular heartbeats. The superiority of the suggested model is verified with other existing techniques.

KEYWORDS: *Cardiac arrhythmia classification, ECG signals, Feature extraction, Dilated temporal convolution network, Spatial attention mechanism.*

INTRODUCTION

Cardiac arrhythmia is a situation in that the rate of the heart becomes irregular, either relatively slow or fast. Though numerous arrhythmias are not serious, some of them can result in heart failure, stroke, and even an unexpected death [6]. The arrhythmia's incidence has enhanced in the present years, especially, the cardiac rhythm abnormality's frequency in the matured to older adults is considerable [7]. There are three categories of arrhythmias including bradycardia, ventricular, and supraventricular [8]. The ECG smart analysis is an efficient strategy for the accurate treatment and the timely prevention of arrhythmia [9]. In the objective ECG waveforms, it is normal to view the multi-label situation in that one patient can be represented with distinct kinds of arrhythmia [10].

Nowadays, deep learning has been utilized for diagnosing arrhythmia, leading to important performance enhancements. But, the complexities are still present in their practical applications [11]. Initially,

though the ECG features obtained utilizing the deep learning mechanisms can offer rich information for the diagnosis of cardiac arrhythmia, it is complex to draw out the unique arrhythmia's features [12]. An individual arrhythmia can have multiple ECG structures in distinct patients due to the diverse temporal and morphological features of the ECG signals. Hence, it is complex to draw out significant ECG features for specific cardiac disease categories utilizing deep learning [13]. Next, numerous experiments have implemented the strategies of arrhythmia classification on the basis of skewed class distribution including minority and majority classes. The minority class defines those with tiny classes in the group, whereas the majority class defines the classes with more examples in the overall data source [14]. The uneven classification approaches have minimum predictive accuracy for the minority classes because the deep learning mechanisms employed for classification are developed considering the same amount of examples for all classes [15]. Therefore, this work presents a new cardiac arrhythmia classification approach by incorporating deep learning.

The contributions of the designed diagnosis process of cardiac arrhythmia are explained below.

- To develop a novel scheme for diagnosing cardiac arrhythmia by utilizing a dilated deep model that ensures timely and accurate treatment of the arrhythmia by reducing the handcrafted features and manual errors. Additionally, this work supports to minimize the workload and the reliance on the experienced analysts.
- To extract the wave and spectral features available from the raw ECG signals for increasing computational efficiency and accuracy. These extracted rich features ensure the timely diagnosis of arrhythmia.
- To implement the DTCN-SA technique for classifying cardiac arrhythmia efficiently. Here, the DTCN minimizes the gradient issues and SA focuses on the important regions thus guaranteeing the accurate classifications.

The developed diagnosis process of cardiac arrhythmia has the upcoming parts. The recent cardiac arrhythmia diagnosis is described in Part II. The materials and methods of a novel approach to cardiac arrhythmia classification are explained in Part III. The feature extraction process and dilated deep learning model for disease classification are illustrated in Part IV. The experimental analysis of the diagnosis scheme is demonstrated in Part V and the conclusion of the diagnosis scheme of cardiac arrhythmia was given in Part VI.

EXISTING WORKS

Literature Review

In 2022, Kim et al. [1] have discovered a classification framework for classifying the arrhythmia. This framework integrated the (BiLSTM) with the residual connections. The work tested with large scale datasets for determining the generalization ability. The model could allow the arrhythmia category's direct diagnosis in clinical experiments on the basis of the minority class's accurate identification.

In 2020, Ganguly et al. [2] have introduced an automated framework for categorizing the arrhythmia utilizing ECG signals and deep learning. This work obtained the necessary features identified in the segmented ECG signals and then provided to the Bi-LSTM method for classification. The solutions described that the feature-aided Bi-LSTM method performed better than the conventional mechanisms. This model was generic and employed for any computer-aided cardiovascular disease diagnosis.

In 2021, Li et al. [3] have presented an ECG-based multi-label feature selection mechanism and constructed a multi-label classification model for arrhythmia by implementing a multi-objective approach. By utilizing the diverse research, the model's feasibility was guaranteed. The solutions offered were optimal for the present algorithms.

In 2022, Mohonta et al. [4] discussed about a deep learning framework, where the scalogram was achieved with the help of Continuous Wavelet Transform (CWT). It was categorized according to the signature relating to the arrhythmia. The model was tested and trained to recognize five kinds of heartbeats. The outcome displayed that the approach could identify the arrhythmia efficiently from the ECG segments and the power for being employed for digital and personalized healthcare.

In 2022, Atal et al. [5] have recommended an automatic classification model for arrhythmia employing the (CNN). This model initially obtained the Gabor and wave features from the raw signals. In the end, the signals were offered to the deep CNN mechanism that recognized the patient ailment as noarrhythmia or having arrhythmia. The techniques were evaluated and achieved high performance.

Research Gaps and Challenges

One of the most prevalent cardiovascular disorders is arrhythmia, which can result in unexpected death and cardiac arrest. Cardiologists primarily consider the heart's rhythm, beat rate, and any changes in its structural features to identify abnormalities in the ECG. Nevertheless, it is not practical to evaluate each individual's heartbeat, which increases inspection complexity and reduces the classification accuracy. Hence, many research works have been implemented for the classification of arrhythmia. Some of the common drawbacks in the prior works are listed below:

- In most conventional models, manual adjustment of several factors that are associated with arrhythmia classification is done. However, these kinds of procedures lead to information loss.
- When calculating the limits and peaks that correspond to the ECG signals, noise and uncertainty are presented. These problems lead to a high level of failure in the classification process.
- Some of the conventional techniques attained poor classification accuracy as they are not focused on extracting relevant features from the input signals that support distinguishing normal and abnormal heartbeats.

These limitations are solved by the developed arrhythmia classification model. Table I gives the advantages and challenges of conventional arrhythmia classification models.

Table 1. Features and Various Challenges of Prevailing Arrhythmia Models using Deep Learning Techniques

Author	Methodology	Identified Features	Identified Challenges
Kim et al. [1]	ResNet and LSTM	It effectively addresses the class imbalance problem. It retrieves unique features with generalization ability.	It takes more training time. It does not handle the generation of noise during the data balancing process.
Ganguly et al. [2]	Bi-LSTM	The computation time of the model is low.	Computational resource requirements are high.
Li et al. [3]	Feature Learning	It effectively selects the most relevant by reducing dimensions and computational complexity. This model considers correlations between different arrhythmias for accurate results.	It requires more targeted optimization for significant outcomes.
Mohonta et al. [4]	CWT	It uses short ECG segments, which makes the model faster and computationally less complex. It considers detailed time-frequency information for efficient outcomes.	The performance of this method is not feasible in large datasets. It does not remove the artifacts in input signals.
Atal et al. [5]	Deep CNN	It effectively fetches the Gabor and wave features from input signals for precise classification.	It needs improvement in handling dynamic features. Computational demands are high.

MATERIALS AND METHODS: A NOVEL APPROACH OF CARDIAC ARRHYTHMIA CLASSIFICATION

Signal Collection

For classifying the cardiac arrhythmia, the below data sources are considered.

Dataset 1 (Arrhythmia): It is gathered through the link "https://archive.ics.uci.edu/dataset/5/arrhythmia", accessed on 2024-09-19. This resource includes 279 attributes, where 206 are considered linearvalued and the remaining are considered nominal. Moreover, this resource includes 452 instances with 3 feature types such as real, integer, and categorical. This resource is a multivariate. It differentiates among the absence and presence of arrhythmia and categorizes that into one of the sixteen groups.

Dataset 2 (ECG Arhythmia Dataset): Using the link "https://www.kaggle.com/datasets/ sadmansakib7/ ecg-arrhythmia-classification-dataset", accessed on 2024-09-19, this dataset is gathered. It is utilized for classifying heartbeats to identify the arrhythmia. Each data in this data source includes five classes unknown beat, fusion beat, normal, supraventricular ectopic beat, and ventricular ectopic beat.

From these data sources, sufficient ECG signals are fetched for validation. The collected ECG signals are defined by . In this, the total count of the acquired ECG signals is represented by .

Fig.1 illustrates the sample ECG signals considered in the implemented diagnosis mechanism of cardiac arrhythmia.

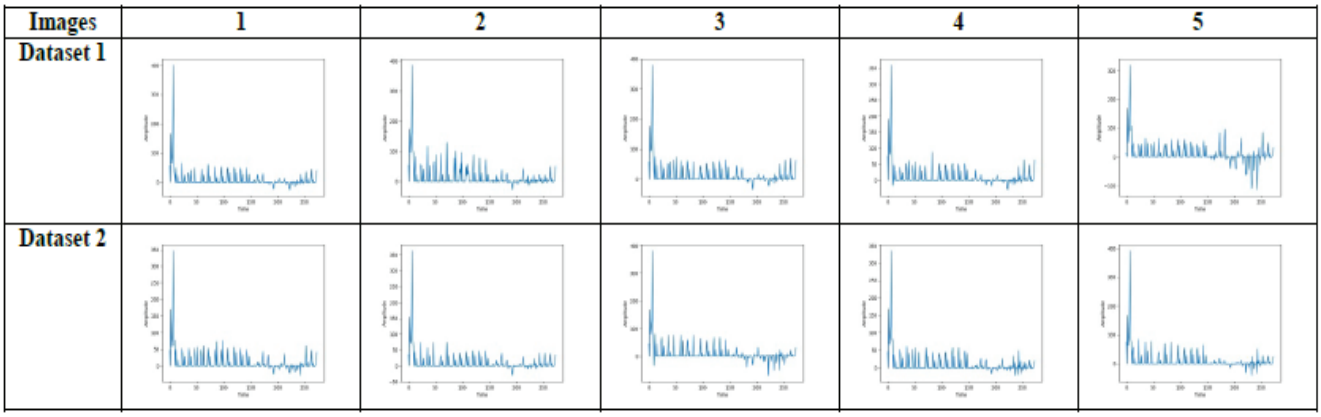


Fig. 1. Sample signals of designed diagnosis process of cardiac arrhythmia

Recommended Classification Model: Cardiac Arrhythmia Disease Diagnosis

Among the numerous cardiovascular disorders, arrhythmia is one of the most dangerous diseases. It refers to the variations in the rhythm or rate of the heartbeats. Abnormal patterns, too slow, or too fast in the heartbeat can be defined as an arrhythmic. The ECG is a largely employed mechanism for diagnosing cardiovascular disorders. It is a non-invasive mechanism that specifies the relaxation and cyclic contraction of the heart muscles. It is employed to recognize heart disorders, heart motions, or extended hearts by estimating the electrical activity's heart.

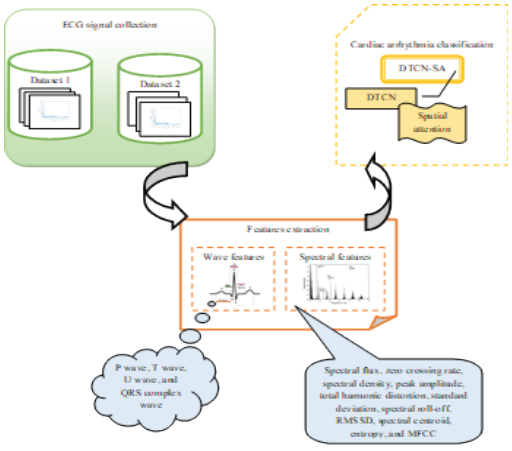


Fig. 2. Pictorial representation of developed an automated diagnosis process of cardiac arrhythmia

Over the previous years, numerous works have been performed in the sector of analyzing and studying the ECG signals to recognize heart disorders. Nonetheless, each kind of arrhythmia takes a special effect and needs a specific kind of treatment. Hence, it is crucial for medical practionaers (cardiologists) to accurately find out the category of arrhythmia before starting the treatment. But, it is not simple to manually recognize the ECG factors because of the important variations in the morphology. Additionally, there is also the likelihood of human error in the evaluation. Thus, there is a requirement for an automated strategy for diagnosing cardiac arrhythmia. The developed automated diagnosis process of cardiac arrhythmia is illustrated in Fig.2.

The deep learning mechanism's development in recent years has generated a significant breakthrough in resolving numerous issues that are present in conventional ML methodologies. It relatively varies from conventional ML, as it does not demand a extraction of features manually and the selection mechanism by learning the important information from the given data automatically. Therefore, by utilizing the deep learning strategy, a novel diagnosis process of cardiac arrhythmia is introduced in this work with ECG signals. For this work, at first from the datasets, the requisite ECG signals are aggregated, and then these signals are employed in the phase of feature extraction. Here, the wave and spectral features are acquired from the ECG signals as it helps to boost the diagnosis process's performance. These rich features are then fed into the newly suggested DTCN-SA technique, where the cardiac arrhythmia is classified. By utilizing this mechanism, the abnormal heartbeats are accurately classified and the final outcomes are analyzed with the previous models. The obtained solutions guaranteed that the presented diagnosis process of cardiac arrhythmia accomplished higher effectiveness than the previous mechanisms.

FEATURE EXTRACTION PROCESS AND DILATED DEEP LEARNING MODEL FOR DISEASE CLASSIFICATION

Wave and Spectral Features

To improve the computational efficiency, the wave, and spectral features are obtained from the raw ECG signals.

Wave features: At first, the raw ECG signals are employed as input. The wave features in ECG define that it is the morphologies and the characteristic patterns of the numerous waves that form the ECG waveform. The ECG wave features like P wave, T wave, U wave, and QRS complex wave are focussed in this extraction process. The extraction of these wave features reduces the feature dimensionality and also improves the diagnosis process in terms of accuracy.

Spectral features: From the raw ECG signals , the spectral features are also extracted. These features are obtained from the signal's frequency domain representation, extracting its significant characteristics and patterns. The spectral structures including flux(spectral) , zero crossing rate, spectral density, peak amplitude, total harmonic distortion, standard deviation, spectral roll-off, RMSSD, spectral centroid, entropy, and Mel-Frequency Cepstral Coefficient (MFCC) are extracted. The extraction of these spectral features helps to improve the outcome of the diagnosis process.

Thus, from the raw ECG signals, the wave and spectral features are extracted and the resultant features are expressed as .

Temporal Convolution Network

The TCN [16] is one of the deep learning frameworks that have been constructed by improving the Convolutional Neural Networks (CNNs) for developing the sequence data. There are a group of 1D convolutional layers are present in the TCN, with distinct dilations. The dilations helped to increase the convolutional layer's receptive field by obtaining the dependencies among the steps that are divided by numerous other steps. The convolution task conducted for the normal TCN layer's i^{th} step is provided in Eq. (1). Here, the TCN convolves from to $I_{t-di.(p-1)}$.

$$Cn(t) = (I *_{di} F)(t) = \sum_{p=1}^{P} F(p) I_{t-di.(p-1)} \quad (1)$$

In his, the input is defined by and the convolution task is specified by $*_d$. The variable F, *i.e*, $F = F(0), F(1), ..., F(P)$, indicates the filter, with filter size for conducting the convolution task. The dilation factor is pointed as di. The filters are utilized to obtain the features, while the dilations are utilized

to present the constant amount of steps among the two subsequent filter taps. Eq. (2) provides the convolution task conducted by the dilated normal TCN layer at the step i^{th} specified as Dn(t). Here, the TCN convolves

$$\text{from } I_{t-d.\left\lceil \frac{p-1}{2} \right\rceil} \text{ to } I_{t+d.\left\lfloor \frac{p-1}{2} \right\rfloor} \quad (1)$$

$$D(t) = (I *_d F)(t) = \sum_{p=1}^{\lfloor P/2 \rfloor} F(\lceil P/2 \rceil + p).I_{t-(d-p)} + \sum_{p=\lfloor P/2 \rfloor+1}^{P} F(P-p+1).I_{t+d(p-\lfloor P/2 \rfloor+1)} \quad (2)$$

The TCNs are more memory efficient than the Recurrent Neural Networks (RNNs). Moreover, the TCNs perform the parallel processing due to the convolution task. Hence, the TCN is a better approach to perform the arrhythmia classification.

Novel DTCN-SA for Classification

For classifying cardiac arrhythmia, the DTCN-SA technique is developed. This technique integrates the TCN model with the dilations and SA mechanisms. The TCN model is efficient in performing the long sequences as it can perform parallel processing. Thus, it takes a very little amount of time for the computations. Moreover, it doesn't demand more memory resources for the computations. Thus, the model is suitable for performing the classification tasks. Nonetheless, the TCN can't cover more information from the outcome attained with each convolution task. To resolve this issue, the DTCN is introduced. The dilation in the TCN can help to cover much information from the outcome attained with each convolution task. Moreover, the dilated convolution supports to enlarge the region of the given image enclosed without pooling. Thus, the DTCN helps in the classification process. In the DTCN [17], the dilation rate is enhanced for the following layers. This helps to improve the receptive field by a sufficient amount without increasing the parameter count. Though the DTCN is helpful in the classification tasks, it still needs to focus more on global information for improving the classification performance. Therefore, the SA mechanism [18] is incorporated with the DTCN for obtaining more global information from the input and achieving better performance in the classification task. The process of the SA is explained as follows. Initially, the input features are passed via the maxpool and avgpool to one of the channel dimensions for achieving the channel descriptions. The channel descriptions are further spliced based on the channel. Next, the weighting attribute of the SA is attained with the support of the convolution and sigmoid activation functions. Further, the achieved weighting attribute is multiplied by the given feature for achieving more derived features after the spatial attention. Thus, the SA gives better focus to all the input features are provides related information of the input. Hence, the DTCN-SA technique is recommended to classify cardiac arrhythmia. In the very beginning, the extracted wave and spectral features are fed into the DTCN-SA technique. In this process, the DTCN efficiently classifies the arrhythmia without losing any significant and related features with the support of SA. Finally, the cardiac arrhythmia classified outcome is obtained. The DTCN-SA-based cardiac arrhythmia classification process is represented in Fig. 3.

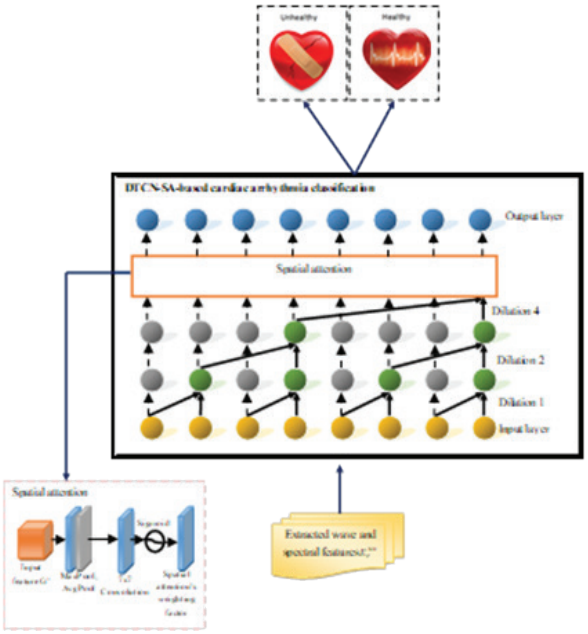


Fig. 3. Representation of DTCN-SA-based cardiac arrhythmia classification

RESULTS AND DISCUSSIONS

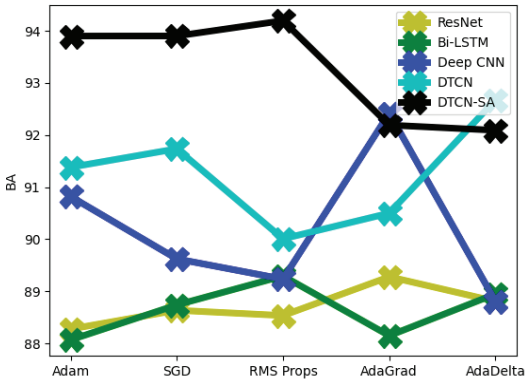
Experimental Setup

Python was applied for implementing the diagnosis process of cardiac arrhythmia. Sufficient experimental

validations were carried out for the designed process by comparing the baseline approaches including ResNet [1], Bi-LSTM [2], Deep CNN [5], and DTCN [17].

Performance analysis of implemented diagnosis process of cardiac arrhythmia

The implemented diagnosis process of cardiac arrhythmia is investigated with baseline approaches using two data sources and the graphical representations are provided in Fig.4 and Fig.5. This evaluation is carried out by altering the optimizers including Adam, AdaGrad, AdaDelta, RMS Props, and SGD. These optimizer-based investigations are improving the training process and also ensuring the deep model's effectiveness. In Fig.4 (g), when focussing on the AdaGrad optimizer, the Matthews Correlation Coefficient (MCC) of the implemented DTCN-SA-based diagnosis process is 6.32% increased by ResNet, 7.47% increased by Bi-LSTM, 3.67% increased by Deep CNN, and 3.44% increased by DTCN respectively. Also, in Fig.5 (f), the False Negative Rate (FNR) of the implemented DTCN-SA-based diagnosis process is 91.6% minimized by ResNet, 54.16% minimized by Bi-LSTM, 58.3% minimized by Deep CNN, and 33.3% minimized by DTCN respectively when focussing the Adam optimizer. Thus, the optimizers-aided experiments illustrated that the developed DTCN-SA-aided diagnosis process of cardiac arrhythmia is highly superior to the baseline techniques. This model helps analysts in the medical sector for treating cardiovascular diseases accurately and timely.



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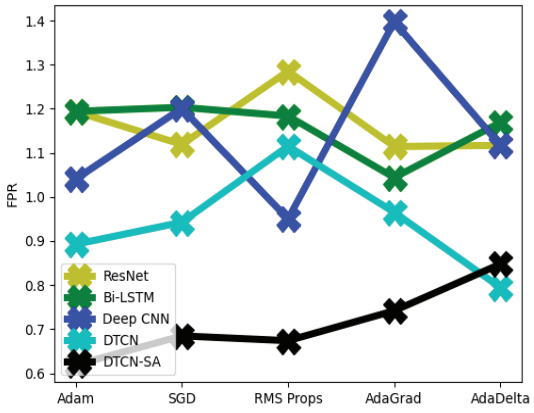

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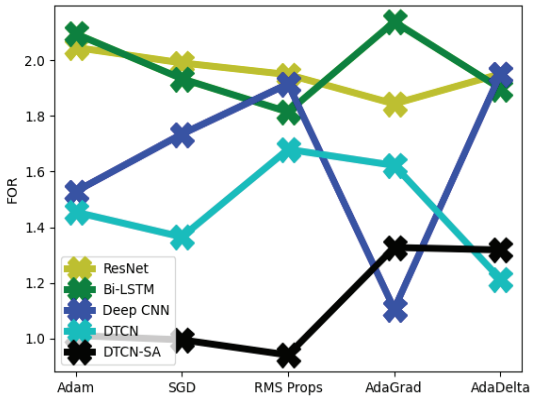

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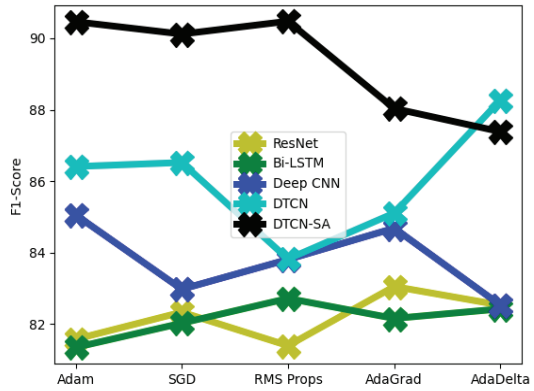

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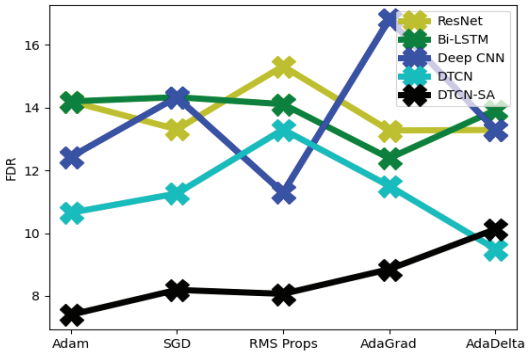

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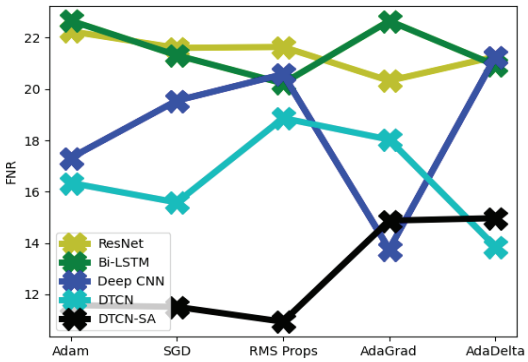

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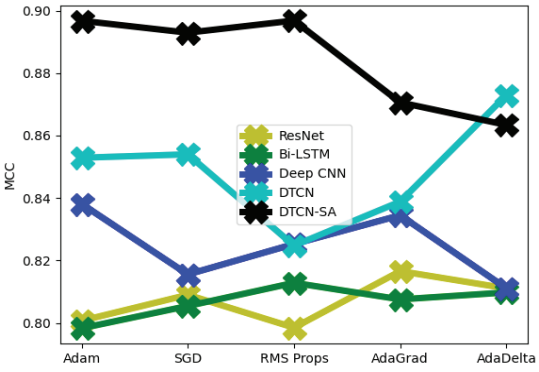
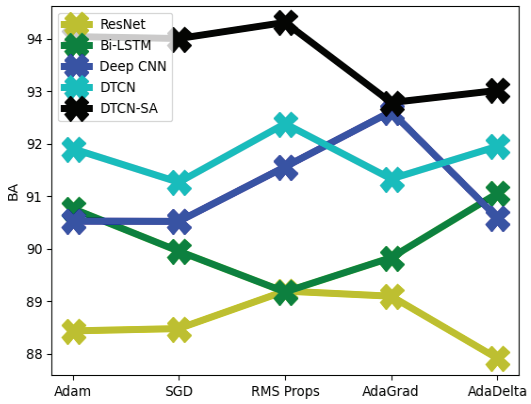


(g)



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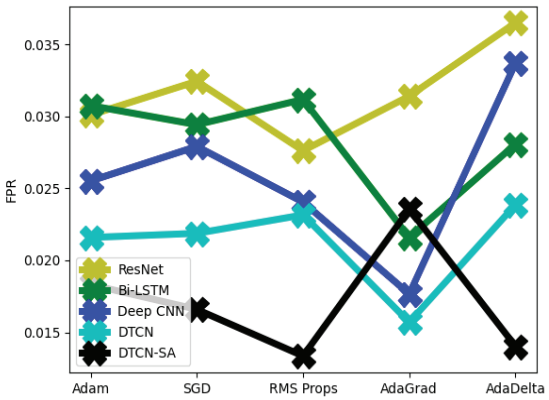

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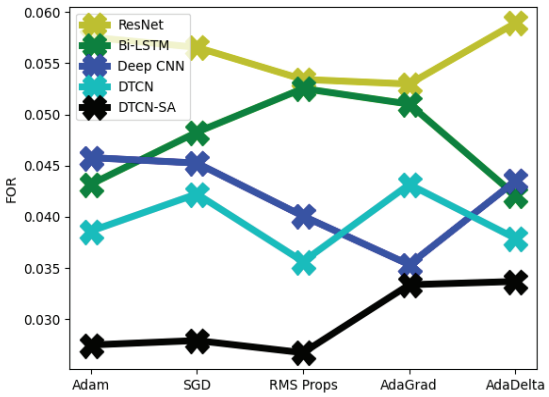
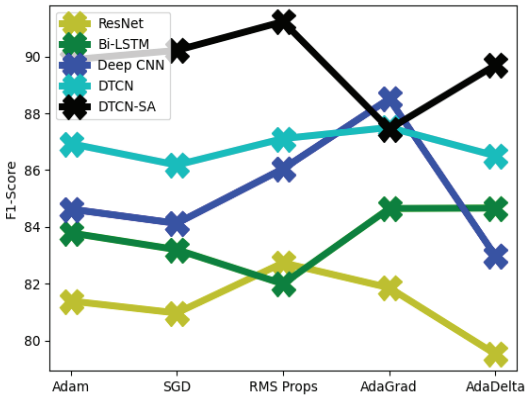


(c)

Fig. 4. Performance analysis of implemented diagnosis process of cardiac arrhythmia over baseline models for first dataset regarding (a) Balanced Accuracy (BA), (b) False Positive Rate (FPR), (c) False Omission Rate (FOR), (d) F1 score, (e) False Discovery Rate (FDR), (f) FNR, and (g) MCC



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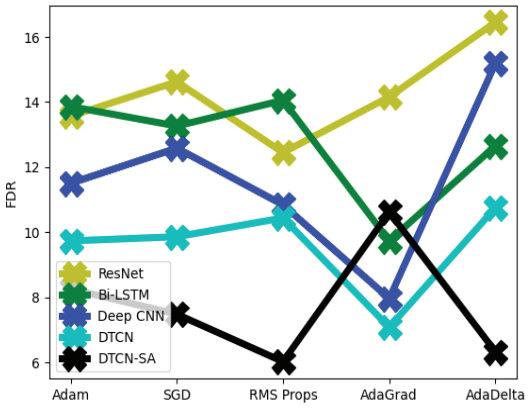

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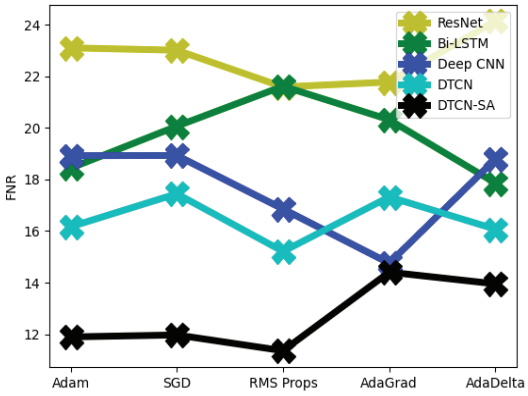
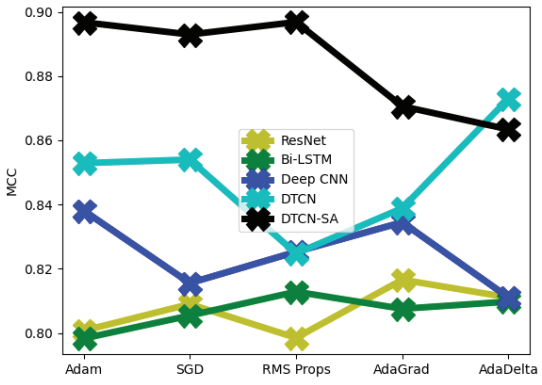


(f)



(g)

Fig. 5. Performance analysis of implemented diagnosis process of cardiac arrhythmia over baseline models for second dataset regarding (a) BA, (b)FPR, (c) FOR, (d) F1 score, (e) FDR, (f) FNR, and (g) MCC

CONCLUSION

With the objective of diagnosing cardiac arrhythmia, this work has explored a new deep network. This network recognized the irregular heartbeats in individuals thus ensuring the life quality. At first, the developed work garnered the ECG signals from distinct data sources, and then from the ECG signals, the wave and spectral features were extracted. After that, the extracted rich features were subjected to the cardiac arrhythmia diagnosis phase, where the DTCN-SA technique was supported for classifying the arrhythmia efficiently. The numerical experiments were performed for the suggested process and contrasted with the previous methods. The BA of the implemented diagnosis process of cardiac arrhythmia was 5.91% improved by ResNet, 2.15% improved by Bi-LSTM, 2.68% improved by Deep CNN, and 1.07% improved by DTCN respectively when focussing the second dataset's AdaDelta optimizer. Hence, the validations were elucidated that the designed diagnosis process of cardiac arrhythmia obtained relatively more accurate solutions than the previous models thus ensuring its supremacy. Though the developed diagnosis process of cardiac arrhythmia is efficient, normally this model is sensitive to noise. Moreover, the DTCN model may be affected by the dimensionality issue. Therefore, future work will be carried out by introducing a pre-processing strategy

and heuristic algorithm for preventing these mentioned limitations.

REFERENCES

1. Omarov, Batyrkhan, et al. "Ensemble Approach Combining Deep Residual Networks and BiGRU with Attention Mechanism for Classification of Heart Arrhythmias." Computers, Materials & Continua 80.1 (2024).
2. Kodavati, Trinaya, et al. "Detection and Classification of Arrhythmia Using Hybrid Deep Learning Model." 2023 International Conference on Next Generation Electronics (NEleX). IEEE, 2023.
3. Sansonetti, Andrea. "Combining Machine Learning and Deep Learning techniques for multi-label classification of ECG with variable number of leads." (2020).
4. Mavaddati, Samira. "ECG arrhythmias classification based on deep learning methods and transfer learning technique." Biomedical Signal Processing and Control 101 (2025): 107236.
5. Atal, Dinesh Kumar, and Mukhtiar Singh, "Arrhythmia classification with ECG signals based on the optimization-enabled deep convolutional neural network," Computer Methods and Programs in Biomedicine, vol. 196, pp.105607, 2020.
6. Honnashamaiah, Anu, and S. Rathnakara. "Classification of Arrhythmia Diseases using Hybrid Novel Models dependent on CNNs and Long Shorter Term Memory with Particle Swarm Optimization Algorithm." International Neurourology Journal 27.4 (2023): 788-799.
7. Escobar-Ordoñez, Julián, et al. "Comparison of 1D Convolutional Neural Networks for Arrhythmias Classification Using ECG Signals." International Conference on Computer Science, Electronics and Industrial Engineering (CSEI). Cham: Springer Nature Switzerland, 2023.
8. Lora, Chandra Prakash, and M. M. Rekha. "Analyzing Bi-directional LSTM Networks for Cardiac Arrest Risk Assessments." 2024 2nd International Conference on Artificial Intelligence and Machine Learning Applications Theme: Healthcare and Internet of Things (AIMLA). IEEE, 2024.
9. Jat, Tarushi, Nagamma Patil, and Prajna Bhat. "Detection of heart arrhythmia with electrocardiography." Network Modeling Analysis in Health Informatics and Bioinformatics 13.1 (2024): 57.
10. Gharoun, Hassan, et al. "Trust-informed Decision-Making Through An Uncertainty-Aware Stacked Neural Networks Framework: Case Study in COVID-19 Classification." arXiv preprint arXiv:2410.02805 (2024).
11. Boaretto, Bruno RR, et al. "The use of entropy of recurrence microstates and artificial intelligence to detect cardiac arrhythmia in ECG records." Applied Mathematics and Computation 475 (2024): 128738.
12. Singh, Prem Narayan, and Rajendra Prasad Mahapatra. "An Automation Detection of Arrhythmia Using DWT-AR Features and Machine Learning." International Conference on Recent Trends in Computing. Singapore: Springer Nature Singapore, 2023.
13. Tambe, Pravin M., and Manish Shrivastava. "Hybrid brave-hunting optimisation for heart disease detection model with SVM coupled deep CNN." International Journal of Intelligent Information and Database Systems 17.1 (2025): 92-123.
14. Bechinia, Hadjer, Djamel Benmerzoug, and Nawres Khlifa. "Enhanced ECG Signals Classification with Image-Driven Ensemble Deep Transfer Learning." International Conference on Computing Systems and Applications. Cham: Springer Nature Switzerland, 2024.
15. Kachuee, Mohammad, Shayan Fazeli, and Majid Sarrafzadeh. "Ecg heartbeat classification: A deep transferable representation." 2018 IEEE international conference on healthcare informatics (ICHI). IEEE, 2018.
16. Salam, Abdu, et al. "Efficient prediction of anticancer peptides through deep learning." PeerJ Computer Science 10 (2024): e2171.
17. Goldbraikh, Adam, et al. "MS-TCRNet: Multi-Stage Temporal Convolutional Recurrent Networks for action segmentation using sensor-augmented kinematics." Pattern Recognition 156 (2024): 110778.
18. Agnes, S. Akila, et al. "Enhancing Remote Sensing Scene Classification with Channel-Spatial CNN (CS-CNN)." International Conference on Intelligent Systems Design and Applications. Cham: Springer Nature Switzerland, 2023.

Deep Learning based Object Detection and Location Estimation

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ABSTRACT

Estimating the location of detected objects in an image is a very useful task for visually impaired people and also for robot navigation. The main objective of my work is to localize the location of detected objects in an image. YOLOv8 deep learning is used to detect objects in real-time images. YOLOv8 enables accurate and very fast object detection. We proposed an OLEA algorithm to estimate the location of detected objects in an image. The OLEA algorithm estimates the coordinates of the object centers and the coordinates to which the detected object belongs.

KEYWORDS: *Object detection, Object recognition, YOLOv8, OLEA (Object Location Estimation Algorithm).*

INTRODUCTION

Locating objects in images has a wide range of applications, especially for robot navigation. Different types of techniques have been proposed to detect objects in background images: template-based, feature-based, machine learning-based, and deep learning-based. Deep learning approaches improve the accuracy of object recognition. Over the years, many different deep learning-based detection approaches have been proposed, each with its own advantages and limitations. YOLOv8 delivers the fastest object detection that adapts to real-time environments. The OLEA algorithm (Object Localization Algorithm) [2] estimates the location of a detected object by calculating the center of the object bounding box and comparing it with the coordinates of the segmented images to determine which segmented image segment belongs to that coordinate. The location of the bounding box center. The OLEA algorithm improves the accuracy of the location estimation. Estimating the location of an object in an image consists of: Object detection using YOLOv8 is presented in Session 3. Location estimation of detected objects using the OLEA algorithm is presented in Session 4. Experimental results are presented in Session 5. Conclusions are presented in Section 6.

RELATED WORKS

Object Detection

Object detection [6, 7] is the process of finding instance objects in an image or video. Deep learning-based approaches offer the best performance in the field of computer vision. Over the years, various deep learning-based detection approaches have been proposed, each of which has its own advantages and limitations. RetinaNet [4, 5], YOLOv8 [8], FPN [1], and Fast R-CNN [22] achieve good detection accuracy.

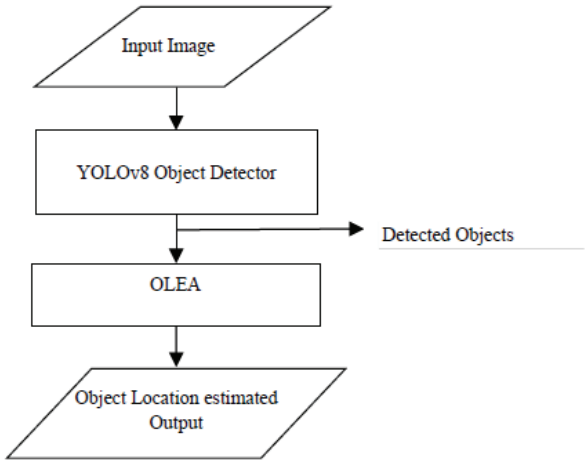

Fig. 1 Overall block diagram of the proposed work

Location Estimation

The Image Object Location Estimation (IOLE) algorithm [2] estimates the location of objects detected by Adaboost [3, 12] by calculating the center of the object bounding box. After the coordinates of the bounding box center are determined, they are compared with the coordinates of the segmented images to find which segment coordinate the bounding box center coordinate belongs to. The IOLE algorithm improves the accuracy of the location estimation.

PROPOSED APPROACH

YOLOv8 Object Detection

YOLOv8 object detector performs fastest multi label classification. YOLOv8 is the latest version of the YOLO (You Only Look Once) family of object detection models. YOLO models are widely used in computer vision tasks, especially real-time object detection, due to their speed and accuracy. The backbone of YOLOv8 is responsible for feature extraction from the input image. It uses a deep convolutional neural network (CNN) optimized for both speed and accuracy. The backbone includes:

Convolutional layer: A standard convolutional layer to capture low-level features. Residual Blocks: Residual connections (e.g. ResNet) to ensure better gradient flow and avoid vanishing gradients.

Normalization and Activation: Batch normalization and activation functions (e.g. ReLU and Leaky ReLU) after each convolution to stabilize and speed up training.

Necks : YOLOv8's necks are designed to aggregate and improve features extracted from the backbone. This includes:

FPN (Feature Pyramid Network): Combines features at different scales to effectively handle objects of different sizes.

PANet (Path Aggregation Network): Improves the feature fusion process by providing more effective paths for information flow.

Head :The head is responsible for generating predictions such as object bounding box coordinates, class values, and confidence values. He proposes that:

Anchor-free mechanism: YOLOv8 can simplify the model and improve performance by using an anchor-free approach. Instead of predefined anchor frames, it directly predicts the object's location and size.

Prediction layers: These layers output the final detection results. They typically consist of a series of convolutions followed by a sigmoid or softmax activation function. Key Innovations

Efficient Convolution: Use more efficient convolution operations such as depthwise separable convolution to reduce the number of parameters and calculations.

Improved Post-Processing: Improved Non-Maximum Suppression (NMS) technique to refine the final detection set.

Advanced Loss Function: Uses advanced loss functions that better balance different components (localization, classification, confidence, etc.) during training.

OLEA Algorithm

Estimates the position of objects in an image.

1. Partition the Input image space into Nine segments, namely Upper-Left, Upper-Center, Upper-Right, Middle-Left, Middle-Center, Middle-Right, Lower-Left, Lower-Center and Lower-Right.

i. Find, height and width of the image.

ii. Initialize, the number of horizontal partition (m) as 3 and vertical partition (n) as 3

iii. Fragment the input image space into 9 (m * n) segments, by

ɯ=width/m

ɯ1=ɯ-1

ɯ2= ɯ1+ ɯ

ɯ3= ɯ2+ ɯ

Where, ɯ1, ɯ2, ɯ3 are the width of the partitioned image segments.

ɧ=height/n

ɧ1=ɧ-1

ɧ2=ɧ1+ɧ

ɧ3=ɧ2+ɧ

Where, ɧ1, ɧ2, ɧ3 are the height of the partitioned image segments

2. Estimate, coordinate values of the center of YOLOv8 detected objects bounding box.

i. Find bboxstartxi, bboxstartyi, bboxWi and bboxHi of the bounding box

ii. Estimate bounding box center by

bboxCi = bboxWi / 2 + bboxstartxi

bboxCyi = bboxHi /2 + bboxstartyi

Center of the bounding box is bboxCi and bboxCyi.

ɯi= ẋi - xi

Ɦi= ẏi - yi

Where, x and y are the coordinates of the start of bounding box from the top left corner or origin of the image ẋ and ẏ are the coordinates of the end of bounding box from the top left corner or origin of the image.

Ẇi=xi +ɯi/2 mw

Ḣi=yi+Ɦi/2 mh

3. Find the position of the detected objects center by compare the estimated center coordinate value of the ith bounding box to the partition segments of the image coordinate values.

if (Ḣi <= ɧ1)

a. if (Ẇi <= ɯ1), then Object is in Upper-Left Coordinate

b. elseif (Ẇi >= ɯ2) then Object is in Upper-Right coordinate

c. else, Object is in Upper-Center Coordinate

else if ((Ḣi >= ɧ1) && (Ḣi <= ɧ2))

a. if (Ẇi <= ɯ1), then Object is in Middle-left Coordinate

b. elseif (Ẇi >= ɯ2), then Object is in Middle-Rigtht coordinate

c. else, Object is in Middle-Center Coordinate

else

a. if (Ẇi <= ɯ1), then Object is in Lower-Left Coordinate

b. elseif (Ẇi >= ɯ2), then Object is in Lower-Right coordinate

c. else, Object is in Lower -Center Coordinate

4. Compare the bounding box coordinate values with the image segments coordinate values to exactly locate the detected Objects.

EXPERIMENTS

The YOLOv8 pre-trained model is used to detect objects in real-time images. The OLEA algorithm is applied to the detected objects to determine the object's location in the image. OLEA displays the object's location according to two criteria, based on estimating the center of the object coordinates and comparing the four bounding box coordinates with the coordinate values of the image segment. The OLEA algorithm accurately estimates the object's location. The performance of location estimation depends on the object detection.

Table. 1. Object Detection Performance comparison of Deep Learning models

Object Detection Model	Precision	Recall	mAP0.5	GFLOPs	Spend (s/img)
YOLOv8s [23]	92.66%	95.21 %	98.39%	28.6	0.0387
YOLOv5s [24]	91.74%	95.99 %	98.12%	16.5	0.0311
Effcientnet -B5 [26]	91.07%	93.48 %	96.68%	9.9	0.0280
Faster-RCNN [25]	94.8%	96.34 %	97.11%	344.4	0.181
SSD [24]	91.79%	92.03 %	95.33%	31.0	0.0470
YOLOv4 [23]	92.05%	92.05 %	95.59%	52.0	0.0818

Fig. 2. YOLOv8 based object detected and OLEA based object located play ground image

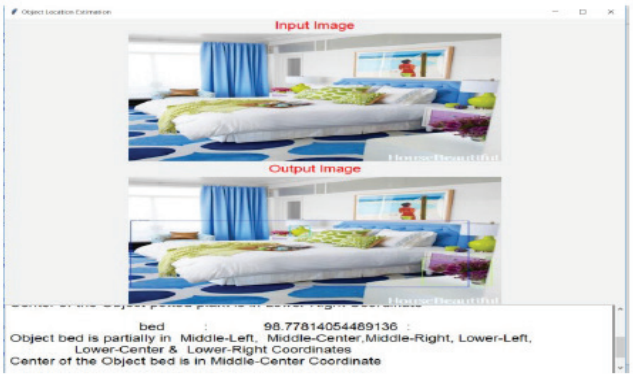

Fig. 3. YOLOv8 based object detected and OLEA based object located Bedroom image

The object location estimation performance of the proposed study mainly depends on the performance of object detection. Fig 2,3, and 4 displays the YOLOv8 object detected and OLEA location estimated sample images. Performance comparison of Deep Learning models is shown in Table 1.

Fig. 4. YOLOv8 based object detected and OLEA based object located Road image

Fig. 5. Workspace of object detection and location estimation.

CONCLUSION

Estimation of the location of the objects present in the real images or videos is high level task in computer vision. Proposed OLEA algorithm accurately locates coordinate position the objects in the images or videos. OLEA can used for robotic navigation and provides virtual visual assistant to the visually challenged persons.

REFERENCES

1. T.-Y. Lin, P. Dollar, R. Girshick, K. He, B. Hariharan, and ´ S. Belongie. Feature pyramid networks for object detection. In CVPR, 2017
2. R. Balamurugan, R. Arunkumar, G. Prabakaran, “Recognition and Location Estimation for Multiple Indoor Static Objects”, IJRTE, Vol. 8, Pages: 5152-5156, July 2019.
3. R. Arunkumar, M. Balasubramanian and S. Palanivel, “Indoor Object Recognition System using Combined DCT-DWT under Supervised Classifier”, IJCA, Volume 82 – No3, pages: 17- 21, November 2013
4. Tsung-Yi Lin, Priya Goyal, Ross Girshick, Kaiming H,e Piotr Dollar “Focal Loss for Dense Object Detection”. arXiv:1708.02002v2 7 Feb 2018
5. R. Balamurugan , R. Arunkumar and S. Mohan,” RetinaNet Based Environment Classification”, AJCST, Vol.7, pp. 112-114, 2018
6. A. Oliva, A. Torralba, Modeling the shape of the scene: A holistic representation of the spatial envelope, IJCV 42 (3) (2001) 145-175
7. J. Wu, J. M. Rehg, CENTRIST: A visual descriptor for scene categorization, TPAMI 33 (8) (2011) 1489-1501
8. Redmon, Joseph Farhadi, Ali “ YOLOv8 An incremental Improvement”, 2018, http://arxiv.org/abs/1804.02767
9. Cheng, X., Lu, J., Feng, J., Yuan, B., & Zhou, J. (2018). Scene recognition with objectness. Pattern Recognition, 74, 474–487
10. L. J. Li, R. Socher, L. Fei-Fei, Towards total scene understanding: Classification, annotation and segmentation in an automatic framework, in: CVPR, 2009, pp. 2036–2043.
11. E. B. Sudderth, A. Torralba, W. T. Freeman, Learning hierarchical models of scenes, objects, and parts, in: ICCV, 2005, pp. 1331-1338

12. M. Stamp, A revealing introduction to hidden markov models, Department of Computer Science San Jose State University.

12. S. Geman, C. Graffigne, Markov random field image models and their applications to computer vision, in: ICM, 1986, p. 2

13. D. M. Blei, A. Y. Ng, M. I. Jordan, Latent dirichlet allocation, JMLR 3 (1) (2003) 993–1022.

15. Olga Barinova, Victor Lempitsky , Pushmeet Kholi, "On detection of multiple object instances using hough transforms," IEEE Trans. Pattern Anal. Mach. Intell., 34, no. 9, pp. 1773–1784, Sep. 2012

16. Junliang Li , Hon-Cheng Wong , Member, IEEE, Sio-Long Lo, and Yuchen Xin, "Multiple Object Detection by a Deformable Part-Based Model and an R-CNN

17. ZHAO Baojun, ZHAO Boya, TANG Linbo, WANG Wenzheng, and WU Chen, " Multi-scale object detection by top-down and bottom-up feature pyramid network", Journal of Systems Engineering and Electronics, Vol. 30, No. 1, February 2019, pp.1 – 12

18. Tsung-Yi Lin, Piotr Dollar´ , Ross Girshick, Kaiming He, Bharath Hariharan, and Serge Belongie "Feature Pyramid Networks for Object Detection", 2017 IEEE Conference on Computer Vision and Pattern Recognition p. 936 -944.

19. B. Janardhana Rao and O. Venkata Krishna, "The Log Polar Transformation for Rotation Invariant Image Registration of Aerial Images", IJCTA, Vol. 4, Pages: 833-840, 2013

20. Wahi, A, Ravi, P. ; Saranya, M.," A neural network approach to rotated object recognition based on edge features: Recognition rate and CPU time improvement for rotated object recognition using DWT" Computing Communication and Networking Technologies (ICCCNT), 2010 , 29-31 July 2010, Pages 1 - 6.

21. Y. Xiao, J. Wu, J. Yuan, mCENTRIST: A multi-channel feature generation mechanism for scene categorization, TIP 23 (2) (2014) 823–836.

22. Girshick, Ross: "Fast R-CNN", Proceedings of the IEEE International Conference on Computer Vision, 2015, pp 1440-1448

23. Jocher, G.; Chaurasia, A.; Oiu, J. YOLO by Ultralytics. Available online: https://github.com/ultralytics/ultralytics (accessed on31 January 2022).

24. Liu, W.; Anguelov, D.; Erhan, D.; Szegedy, C.; Reed, S.; Fu, C.Y.; Berg, A.C. Ssd: Single Shot Multibox Detector. In EuropeanConference on Computer Vision; Springer: Cham, Switzerland, 2016; pp. 21–37.

25. Ren, S.; He, K.; Girshick, R.; Sun, J. Faster r-cnn: Towards real-time object detection with region proposal networks. Adv. NeuralInf. Process. Syst. 2015,28, 1137–1149.

26. Tan, M.; Le, Q. Efficientnet: Rethinking model scaling for convolutional neural networks/International conference on machinelearning. Proc. Mach. Learn. Res. 2019,97, 6105–6114.

Kokborok Cardinal Identification For NER

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ABSTRACT

Named Entity Recognition (NER) plays a pivotal role in Natural Language Processing (NLP), involving the critical task of extracting essential information from textual data. This research paper is dedicated to the development of an NER system tailored for the Kokborok language, encompassing the identification of both cardinal numbers and classifiers. Kokborok, a Tibeto-Burman language spoken in the northeastern reaches of India, stands out as a classifier language, characterized by a robust system for counting.In this study, we delve into two distinct approaches: rule-based and statistical techniques. Initially, we formulated a set of rules, rooted in the syntactic structure of Kokborok, to discern the precise placement of cardinal numbers and classifiers within the text. Subsequently, we employed a statistical model, training it on a manually annotated corpus to recognize these linguistic entities. Our experimental findings resoundingly demonstrate the superior performance of the rule-based approach in identifying cardinal numbers compared to the statistical method. Our system achieves an impressive F-score of 0.98, underscoring its effectiveness in the realm of Kokborok NER. This research contributes significantly to the development of NER systems for lesser-studied languages and underscores the value of linguistic resources and rule-based methods in such contexts.

KEYWORDS: *NLP, NER, CRF, Cardinal, Rule-based, Machine Learning, Kokborok.*

INTRODUCTION

Named Entity Recognition (NER) is the procedure of categorizing and recognizing specific words within a given sentence and assigning them to predefined groups or entities. NER relies on having predefined named entities and entails the task of classifying and pinpointing these predetermined entities, making it a subset of information extraction. These entities can encompass various categories such as names of locations, individuals, organizations, numerical values, and more. Named Entity Recognition essentially involves the computational analysis aimed at identifying the desired entities. In this paper we try to study the Kokborok cardinals as the named entity.

Cardinal number [1] system tells us the answer to the question 'how many'. The cardinal number system is a fundamental concept that provides answers to the question 'how many.' It functions as a named entity because it furnishes information about quantity. In our Kokborok Named Entity Recognition system, we have incorporated "cardinal" as one of the recognized named entities. In the English language, cardinals encompass a broad range of numerical values, including examples like "one," "five," "seven," "11," "15," "25," "thirty," "fifty," "55," "57," and so forth. These cardinals are vital in conveying information regarding the quantity of items or individuals. Named entity recognition finds applications across diverse fields, including question answering, machine translation, information extraction, summarization, and more. The number system can extend its utility by providing information related to currency, quantity, percentages, years, and other pertinent aspects. In the Kokborok language, a classifier system is employed for counting purposes, contributing to the richness and specificity of the information conveyed through named entities.

A classifier [2] is a word or an affix that expresses the classification of a noun. Classifiers are defined as morphemes which occur 'in surface structures under specific conditions', denoting 'some salient perceived

or imputed characteristics of the entity to which an associated noun refers' [3]. Numeral classifiers are, probably, the most commonly recognized type of classifiers, and are usually defined as classifying morphemes prototypically attached to numerals and expression of quantity[4].The use of numeral classifiers within counting systems is infrequently observed in the English language, and its prevalence is not widespread in other European languages either. Conversely, this system is extensively employed in various Asian languages, including Chinese, Japanese, Korean, and others. Many languages spoken in the northeastern regions of India also adopt numeral classifiers, particularly those within the Tibeto-Burman language family. Among Indian languages, the Bodo-Garo subgroup of the Tibeto-Burman language family distinguishes itself through its extensive utilization of numeral classifiers. In contrast, English falls into the category of non-classifier languages where such classifiers are not a standard feature. It's noteworthy that both Assamese and Bengali, while not as reliant on numeral classifiers as the Bodo-Garo languages, do exhibit some degree of usage. This phenomenon can be attributed, in part, to social interactions and contact between these language communities and the Bodo-Garo groups in Assam, including the Bodos and Rabhas. In contrast, the Kuki-Chin group of languages in Northeast India tends to employ fewer numeral classifiers when compared to the Bodo-Garo group. The variation in the usage of numeral classifiers across these languages underscores the rich linguistic diversity present in the region.

KOKBOROK CLASSIFIERS AND NUMBER SYSTEM

Kokborok is a classifier language, which means it employs bound morphemes as prefixes to numerals for the purpose of enumeration. In Kokborok, classifiers are primarily monosyllabic, with a few exceptions having disyllabic roots. The typical syntactic order in the language is Noun + Classifier-Numeral (N+CL-Num), where the numeral classifier usually comes after the head noun. The Kokborok language employs a classifier-based counting system, where numbers are never used in isolation. Instead, numbers are always accompanied by a prefix (classifier), and in some cases, an additional suffix. The prefix, acting as the classifier, conveys information about the nature of the objects being counted. Kokborok has a robust classifier system with more than sixty distinct classifiers. These classifiers provide insights into the characteristics of the objects under consideration, such as their shape or size.

For instance, when counting human beings, the classifier 'khorok' is used, while 'dul' is employed for round-shaped objects. When enumerating animals, the classifier 'mang' is used. Therefore, by examining the cardinals or numbers in Kokborok, one can discern the specific type of objects being counted. It's worth noting that numbers from one to ten are more commonly used than higher numbers, possibly influenced by other languages. The numerals in Kokborok follow a decimal system (base ten), and there is an absence of a vigesimal system (base twenty). In cases of classifier usage or compounding, the numeral always follows the noun in Kokborok, adhering to a consistent grammatical structure.

Table 1. Kokborok number system

Numbers	English	Kokborok
1	One	Sa
2	Two	Nwi
3	Three	Tham
4	Four	Brwi/bwrwi
5	Five	Ba
6	Six	Dok
7	Seven	Sni
8	Eight	Char
9	Night	Chuku
10	Ten	Chi
11	Eleven	Chisa
12	Twelve	Chinwi
20	Twenty	Khol/Nwichi
21	Twenty one	Nwichisa

Classifiers are obligatorily used with numerals if it is enumerated in Kokborok as shown below:

- Borok khorok-sa

  Person CL- one

  'One person'

- Bwlailai-sa

  Leaf CL-one

  One leaf

- Thaichukthai-sa

  Fruit CL-one

  One mango

The pattern for numeral classifier in the Kokborok number system is given below.

- NCL_1 = CL+NUM (1)
- NCL_2 = CL+NUM+Suf (2)
- NCL_3 = EM+CL+NUM (3)
- NCL_4 = EM+CL+NUM+Suf (4)

Where NCL is the numeral classifier, CL is the Classifier, NUM-is denoted by Number, EM is the representation of the Emphasis Marker consisting of the first syllable of the classifier and Kokborok suffix is denoted by Suf.

It is observed that the numerals classifier in Kokborok follows the mentioned pattern. In certain instances, a prefix is added alongside the classifier. This prefix typically consists of the first syllable of the classifier, with the addition of the word 'se,' serving to emphasize the word. This emphasis marker (EM) enhances the prominence of the numerals classifier, drawing attention to it within the context of the sentence or discourse.

Classifier used in Kokborok

Some of the common classifiers that are used in Kokborok are as given below:

Table 2. Kokborok numeral classifier

Sl No	Classifier (CL)	Numbers (one)	Word (CL-one)	Uses/Example
1	Bar	Sa	Bar-sa	One flower
2	Bisi	sa	Bisi-sa/ bisa	One year
3	Chap	Sa	Chap-sa	One-fold
4	Dam	sa	Damsa	Cloak Time
5	Dek	sa	Deksa	One branch
6	Dibor	sa	Dibor-sa	One working day
7	Dol	sa	Dol-sa	One group
8	Dul	sa	Dul-sa	One round object
9	Hor	sa	Hor-sa	One night
10	Kai	sa	Kai-sa	One thing (non-living)
11	kara	sa	Kara-sa	length from thumb to middle finger
12	khak	sa	Khak-sa	(one) half
13	khob	sa	Khob-sa	one mouthful
14	khok	sa	Khok-sa	One rupee (money)
15	khorok	sa	Khorok-sa	One person (Human being)
16	khor	sa	Khor-sa	One hole
17	khotol	sa	Khotol-sa	One room
18	khung	sa	Khung-sa	House or having roofs
19	kol	sa	Kol-sa	Grains
20	kong	sa	Kong-sa	stem/ cylindrical long object
21	kuri	sa	Kuri-sa	counting in 20s
22	lab	sa	Lab-sa	Piece
23	lai	sa	Lai-sa	leaf/page
24	lam	sa	Lam-sa	Hole apart from the ground(earth)
25	lep	sa	Lep-sa	round flat things
26	mochom	sa	Mochom-sa	Handful
27	mon	sa	Mon-sa	Weight counting in 40s
28	pod	sa	pod-sa	One (different) Item
29	Muk	Sa	Muk-sa	Length hand upto elbow
30	phai	sa	Phai-sa	one meal
31	phang	sa	Phang-sa	tree
32	phari	sa	Phari-sa	weight counting
33	Phon	Sa	Phon-sa	piece

34	phung	sa	Phung-sa	beating
35	rang	sa	Rang-sa	One sip (drinking)
36	sal	sa	Sal-sa	One day
37	taal	sa	Taal-sa	One month
38	tang	sa	Tang-sa	One song
39	Thai	sa	Thai-sa	One fruit
40	Thop	sa	Thop-sa	One drop
41	Thum	sa	Thum-sa	One group
42	Twng	sa	Twng-sa	One hair
43	Wai	sa	Wai-sa	once
44	Yak	sa	Yak-sa	One hand
45	Khuri	sa	Khuri-sa	One glass
46	Kap	sa	Kap-sa	One cup
47	Piyang	sa	Piyang-sa	One Plate
48	Ma (mak)	Sa	Ma-sa	One thing (living)
49	Phil	Sa	Phil-sa	Anniversary
50	Jor	Sa	Jor-sa	One pair
51	Kang	Sa	Kang-sa	Paper, book, clothes etc.

Kokborok is a linguistically rich language, characterized by its morphological complexity. Words in Kokborok can take on various forms due to the presence of suffixes. In our study, we've implemented the Kokborok stemmer method developed by Debbarma [5]. This stemmer employs the longest suffix removal approach to simplify words. Kokborok employs numerous suffixes in various contexts. However, our research has revealed that the following suffixes are specifically utilized as numeral classifiers in the Kokborok counting system: 'no,' 'da,' 'diba,' 'ya,' and 'phu.' These classifiers play a crucial role in the language's numeral counting system. After removing the suffix from a word, our analysis involves checking whether the word ends with Kokborok numbers. It's worth noting that some Kokborok numbers, such as 'sa,' may also function as common word endings and be used as suffixes to convey different meanings within the language. This distinction is important in accurately identifying and interpreting Kokborok words and their numerical components.

Eg. Mwsa- tiger

Bwsa- son

Kwsa- wound

Tamosa - what

kisa - small

Hence merely checking the word, if it is ending with the Kokborok numbers will not be able to identify the correct Kokborok numbers. We must check the presence of the classifiers so as to know if the particular word is a number or not. Thus, the analysis of numeral classifier will let us know the Kokborok number system.

RULE BASED KOKBOROK CLASSIFIER:

The rule-based method leverages linguistic data from the language. We have previously discussed the cardinal formation pattern of Kokborok language in section 2 of this paper. Utilizing this linguistic data, we have established guidelines for the recognition of cardinal numbers. Below, you can find the flowchart diagram illustrating the rule-based approach:

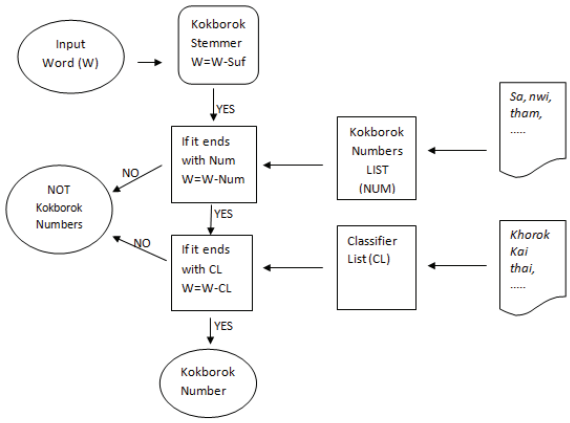

Fig. 1: Kokborok Numeral Classifier Identification

Classifier identification algorithm

i. Apply stemmer for {Word}

ii. Word={Word} - {Suf}

iii. CL={CL1, CL2, CL3….}

iv. If {Word} endswith {NUM}

a. Find Numbers (NUM)

b. Word={Word} – {NUM}

c. If word = CL

i. Return CL, NUM

d. Else If {Word } endswith {CL}

i. EM={Word} – {CL}

ii. Return EM, CL, NUM

CRF BASED KOKBOROK CLASSIFIER

Conditional Random Field (CRF) stands as a valuable statistical modeling technique in the realm of sequence labeling, where it leverages the information from neighboring entities. It can be succinctly described as a conditional sequence model that calculates the probability of a hidden state sequence based on observed data. These models have gained prominence in the domains of pattern recognition and machine learning. Notably, McCallum and Li [6], applied CRFs to address the Named Entity Recognition (NER) problem. They introduced a feature set specifically tailored for identifying named entities and achieved a commendable accuracy rate of 84% during their participation in the CoNLL shared task for the English language.

The inception of Conditional Random Fields (CRFs) can be attributed to Laferty et al [7]. Lafertyhas defined Conditional random fieldas:

Conditional Random Field for a given observation of sequence X and for the leveled sequence Y can be represented as

Definition: *Let G = (V,E) be a graph such that Y = $(Y_v)_{v\in V}$, so that Y is indexed by the vertices of G. Then (X,Y) is a conditional random field in case, when conditioned on X, the random variables Y_v obey the Markov property with respect to the graph: $p(Y_v|X, Y_w, w\neq v) = p(Y_v|X, Y_w, w\sim v)$, where $w\sim v$ means that w and v are neighbors in G.*

Conditional Random Field for a given observation of sequence X and for the leveled sequence Y can be represented as

$$\frac{1}{Z}\exp\left(\sum_j \lambda_j t_j(y_{i-1}, y_i, x, i) + \sum_k \mu_k s_k(y_i, x, i)\right) \quad (1)$$

For xas named entity word sequence {Aisrangninokwngkha Agartala} and y representing the tagged output level sequence {PER, O, O, O, LOC} the t_j (y_{i-1}, y_i, x, i) is considered the transition feature function of the observation sequence, and the labels at positions i and i-1 in the label sequence; s_k (y_i, x, i) is a state feature function of the label at position i and the observation sequence; and λ_j and μ_k are parameters to be obtained during training data and Z is the normalization factor.

The transition function can be represented as:

$$t_j(y_{i-1}, y_i, x, i) = \begin{cases} b(x,i) & if\ y_{i-1} = O\ and\ y_i = LOC \\ 0 & otherwise \end{cases} \quad (2)$$

$$b(x,i) = \begin{cases} 1 & if\ the\ word\ at\ i^{th}\ position\ is\ 'Agartala' \\ 0 & Otherwise \end{cases} \quad (3)$$

In the context of named entity recognition, we employed Conditional Random Fields (CRF) as our chosen technique for predicting named entities based on the training tag set. CRFs are graphical models that lack directionality and are trained conditionally to make output predictions. These models are particularly well-suited for tasks involving sequence modeling, such as named entity recognition.

Our implementation of CRF for named entity recognition utilized the Stanford CRFNER system, specifically the CRFClassifier developed by (Finkel, Grenager, and Manning in 2005) at Stanford University. The foundation of achieving accurate results in named entity recognition lies in the careful construction of features.

In our approach, we incorporated a set of features, including N-grams, the current word, the previous word, and sequences of previous and next words. These features were generated by the CRFClassifier itself. The data format employed by the Stanford CRF Classifier closely resembles the Conll2002 data format, which was initially utilized in the CoNLL-2002 Shared Task for Language-Independent Named Entity Recognition. In this format, each word is tagged on a separate line, with named entities receiving their respective tags, while non-named entities are tagged as “O” to denote being outside of any named entity.

RESULT & DISCUSSION

Our knowledge-based system, designed for identifying and recognizing Kokborok numeral classifiers, consistently delivers accurate results for number identification. Our research is based on an extensive dataset comprising 83,195 tagged entries, within which 747 have been tagged as Kokborok cardinal numbers. Utilizing our rule-based approach, we achieved the following results:

- Precision (P) = 0.98936

- Recall (R) = 0.98543

- F-Score = 2 × (P × R) / (P + R) = 0.98739

In addition to our rule-based approach, we also explored a machine learning-based method for Kokborok cardinal number identification. We employed the conditional random field (CRF) technique for prediction, splitting the training and test data in a 7:3 ratio. The results obtained with the CRF method were as follows:

- Precision = 0.7232

- Recall = 0.9970

- F-Score = 0.8383

It's worth noting that our rule-based approach outperforms the machine learning algorithm, although the difference in performance is relatively marginal. The knowledge-based approach remains slightly superior in terms of accuracy and precision.

CONCLUSION

In conclusion, our research has centered on the Kokborok cardinal numbers and their application in named entity recognition (NER). We have explored two distinct methodologies for NER: a rule-based approach and a machine learning-based approach utilizing Conditional Random Fields (CRF). The rule-based method, which leverages predefined linguistic rules and patterns, yielded an impressive F-score of 0.98. This approach demonstrated high accuracy and precision in identifying named entities within the Kokborok text corpus. It showcased the efficacy of linguistic knowledge and expert-crafted rules in the NER task. On the other hand, the machine learning-based method employing CRF achieved an F-score of 0.87. While marginally lower than the rule-based approach, this method showcased the potential of automated, data-driven techniques for NER. It exhibited adaptability and scalability by learning from the data itself.

Our study underscores the strengths and trade-offs of these two NER methodologies in the specific context of Kokborok. The rule-based approach excels in precision and fine-tuned control, while the machine learning-based CRF approach offers flexibility and scalability. The choice between these methods should depend on the specific requirements and resources available for NER tasks in Kokborok or similar languages. Ultimately, our research contributes valuable insights to the broader field of NER, showcasing the importance of choosing the right approach based on the linguistic characteristics and data availability of the target language.

REFERENCES

1. https://www.mathsisfun.com/numbers/cardinal-ordinal-nominal.html, accessed on 08/05/2023

2. https://glossary.sil.org/term/classifier, accessed on 08/05/2023

3. Allan, K. (1997). Classifiers" Language. . Journal of Linguistic Society of America Vol.53 (2), 285-311.

4. Croft, W. (1994). Semantic universals in classifier systems. Word, 45(2), 145-171.

5. Debbarma, A. (2014). A Simple Kokborok Word Stemmer and its Application in Spell Checking System. In Future Computing, ISBN: 978-81-8487-271-2 . Narosa Publishing House.

6. McCallum, A. & Li, W., 2003. Early results for named entity recognition with conditional random fields, feature induction and web-enhanced lexicons. s.l., s.n.

7. Laferty, J. D., McCallum, A. & Pereira, F. C. N., 2001.. Conditional random fields: Probabilistic models for segmenting and labeling sequence data. s.l., s.n.

Stress Analysis and Alerting System for Online Employees

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ABSTRACT

In today's world, stress has become very much common in most employees who are working in multinational companies. The stress levels have drastically changed in online employees during and after the COVID-19 pandemic. This paper aims to find the stress levels of online employees and to alert them if they are in a critical stress level. The system we have proposed here will measure various parameters of the employee in real time. The main reason behind developing the system is that prolonged online working leads to critical health issues. This system utilizes various sensors to accurately assess stress levels by monitoring physiological and behavioral indicators.

KEYWORDS: *Stress, Alerts, Online, Employee, Pandemic.*

INTRODUCTION

In the current digital era, the shift towards online and remote work has been significant, especially accelerated by the COVID-19 pandemic [1]. This transition has brought about numerous advantages, such as increased flexibility and the ability to work from virtually anywhere [2]. However, it has also introduced a set of challenges, notably an increase in stress levels among online employees. Stress, when unmanaged, can lead to severe health issues, affecting both physical and mental well-being [3]. Multinational companies (MNCs) have observed a significant rise in stress-related problems among their workforce, emphasizing the need for effective monitoring and management solutions. The unique stress factors associated with remote work, such as isolation, blurred boundaries between work and personal life, and constant connectivity, necessitates innovative approaches to stress management [4-5].

This paper presents a comprehensive system designed to analyze and manage stress levels in online employees [6-7]. The system employs a combination of sensors, including a Galvanic Skin Response (GSR) sensor, temperature sensor, and pulse oximeter sensor, to monitor various physiological parameters indicative of stress. The data collected by these sensors is processed using an ESP 8266 microcontroller, which communicates the information to a web dashboard for real-time monitoring. Key features of the system include real-time stress level alerts and emergency notifications. If critical stress levels are detected, a buzzer is activated to alert the employee, and an emergency push button can be used to call for immediate assistance. Additionally, the web dashboard provides a user-friendly interface for continuous monitoring and offers personalized recommendations based on the analyzed data.

The primary goal of this system is to preemptively address stress-related health issues by providing timely interventions and support. By integrating advanced technology with practical health management strategies, the system aims to enhance the overall well-being, productivity, and job satisfaction of online employees. The development and implementation of such a system are crucial in adapting to the evolving dynamics of the modern workforce, ensuring that the benefits of remote work do not come at the cost of employee health.

PROPOSED SYSTEM

The proposed system for stress analysis and care prediction is designed to monitor and manage the stress levels of online employees in real time. This

system integrates multiple sensors, a microcontroller, a web dashboard, and alert mechanisms to provide a comprehensive solution for stress management. Below is a detailed description of each component and their functionalities:

1. Galvanic Skin Response (GSR) Sensor [8]: The GSR sensor measures the electrical conductance of the skin, which varies with its moisture level. Since sweating is controlled by the sympathetic nervous system, GSR can provide valuable data regarding an individual's stress levels.
2. Temperature Sensor [9]: This sensor monitors the body temperature of the employee. Stress can cause fluctuations in body temperature, and tracking these changes helps in assessing stress levels more accurately.
3. Pulse Oximeter Sensor [10]: The pulse oximeter measures the blood oxygen saturation (SpO2) and pulse rate. Both of these parameters can be affected by stress, making them crucial indicators for real-time stress monitoring.
4. The ESP 8266 microcontroller [12-13]: It serves as the central processing unit of the system. It collects data from the sensors and processes it to determine the stress levels of the employee. The ESP 8266 is chosen for its efficiency and capability to handle multiple data streams while offering reliable wireless communication.
5. Web Dashboard [12]: The data processed by the ESP 8266 is transmitted to a web dashboard. This dashboard provides a user-friendly interface where employees and management can monitor stress levels in real time. The dashboard displays various metrics collected by the sensors and highlights any critical changes that may indicate high stress.
6. LCD Display [12]: It is mainly used to display the various parameters of a person in the display.
7. I2C module [13]: A 16x2 LCD display can also be interfaced using an I2C module, reducing the number of required pins and simplifying wiring.
8. Buzzer [12]: In case the system detects that the stress levels have reached a critical threshold, an audible buzzer is activated. This immediate alert helps the employee to recognize the need to take a break or engage in stress-relief activities.
9. Emergency Push Button: The system includes an emergency push button that employees can press if they feel overwhelmed or in need of immediate assistance. Activating this button can trigger predefined actions such as notifying a supervisor or a health professional.

The block diagram for the proposed system is shown in fig.1.

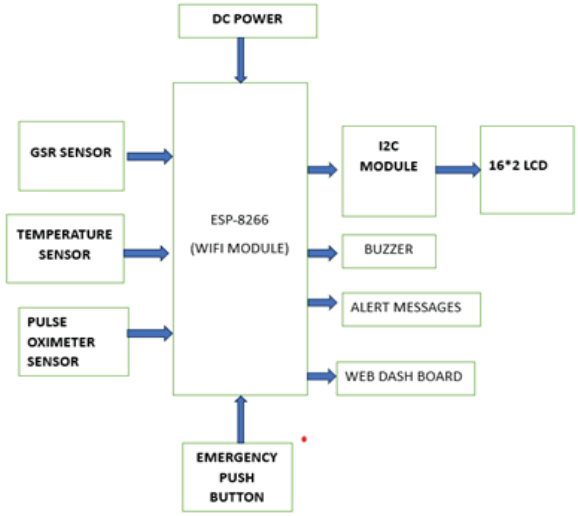

Fig.1: Block diagram for the proposed system

RESULTS AND DISCUSSION

The system consists of different sensors which measures the stress level based on temperature values, Heart Rate and Resistance of a skin. The measured values are used to determine the stress level of every individual. The working model of the system is shown in fig.2.

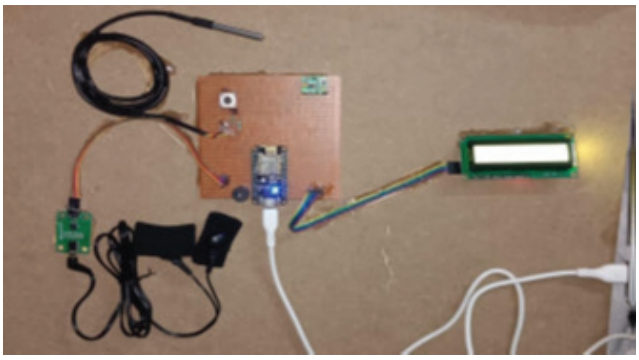

Fig. 2: Working model of the proposed method

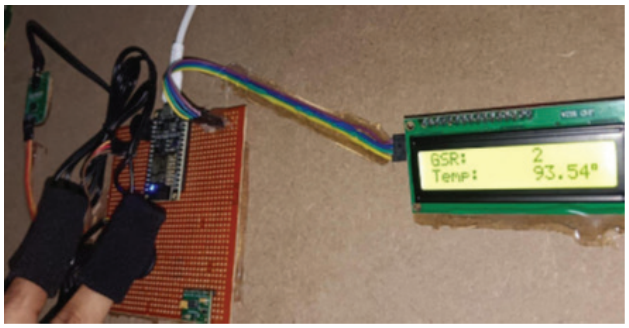

Fig.3: Temperature measurement

The temperature that has been measured with DS18B20 temperature sensor and it has been displayed on the LCD as 93.54° F.

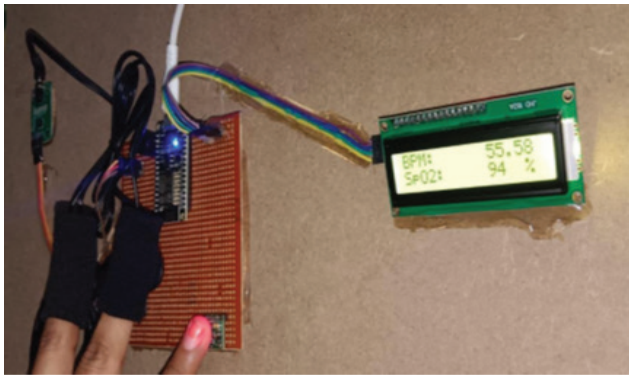

Fig. 4: Heart rate and oxygen level measurement

The heart rate and oxygen level that has been measured with MAX30100 Pulse oximeter sensor and it has been displayed on the LCD as BPM- 55.58 and SPO2 -94%. As the proposed system is also supporting the web based parameters display as shown in fig. 5.

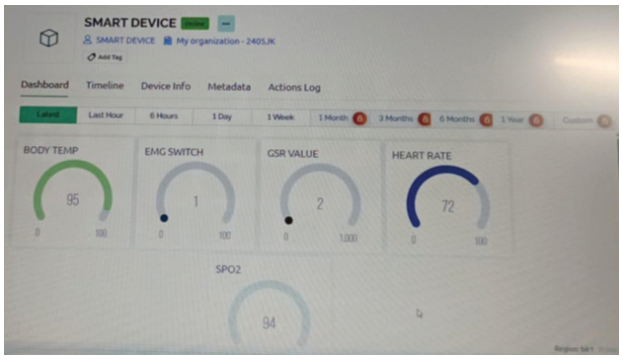

Fig. 5: Web based parameter display

The body temperature, GSR value, heart rate and oxygen levels that has been recorded which is displayed on the LCD display is also updated in the Blynk dashboard using Blynk cloud that is shown in fig.5. When something abnormal happens it immediately alerts the employee using the buzzer to alert their family members and also sends the messages to the concerned people where action can be taken. This scenario is shown in fig. 6.

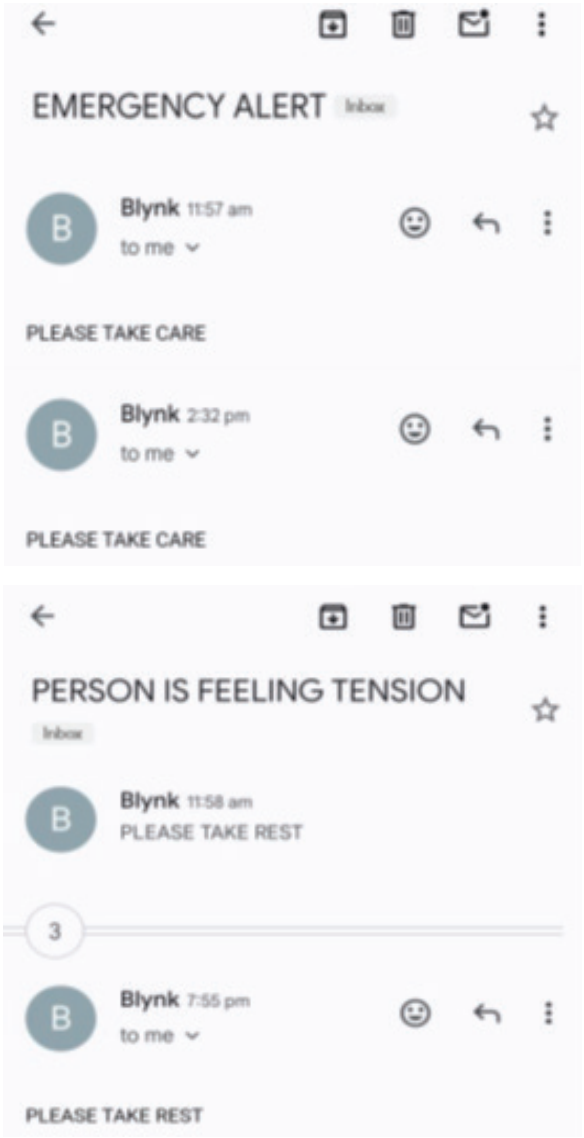

Fig. 6: Emergency messages

The proposed stress analysis and alert system is a valuable work for managing stress among online employees. By providing real-time monitoring, alerts, and personalized recommendations, the system helps in mitigating the adverse effects of prolonged stress.

CONCLUSION

The proposed system for stress analysis and care prediction for online employees has shown to be very effective. The system uses various sensors like GSR, temperature, and pulse oximeter to monitor stress levels accurately. The ESP 8266 microcontroller processes this data and displays it on a 16x2 LCD screen and a web dashboard, making it easy for employees to see their stress levels in real-time. The system's alerts, through a buzzer and an emergency push button, help employees take immediate action when their stress levels are too high. Employees found the system easy to use and helpful in managing their stress. Personalized recommendations provided by the system were especially appreciated. The system can be easily integrated into different work environments and can be scaled up to monitor more employees or adapted for different workplace settings. This makes it a practical and versatile solution for managing stress in remote work settings.

REFERENCES

1. Allen, Tammy D., Timothy D. Golden, and Kristen M. Shockley. "How effective is telecommuting? Assessing the status of our scientific findings." Psychological science in the public interest 16.2 (2015): 40-68.
2. Loia, Francesca, and Paola Adinolfi. "Teleworking as an eco-innovation for sustainable development: Assessing collective perceptions during COVID-19." Sustainability 13.9 (2021): 4823.
3. Juna, Muhamad Azuwan, et al. "Working from home, COVID-19 and multi-dimensional model of well-being theory." International Journal of Work Organisation and Emotion 13.3 (2022): 230-259.
4. Sigursteinsdottir, Hjordis, and Fjola Bjork Karlsdottir. "Does social support matter in the workplace? Social support, job satisfaction, bullying and harassment in the workplace during COVID-19." International journal of environmental research and public health 19.8 (2022): 4724.
5. Lee, Youngjae, et al. "Effects of mental and physical fatigue inducing tasks on balance and gait characteristics." Proceedings of the Human Factors and Ergonomics Society Annual Meeting. Vol. 63. No. 1. Sage CA: Los Angeles, CA: SAGE Publications, 2019.
6. Xiao, Yijing, et al. "Impacts of working from home during COVID-19 pandemic on physical and mental well-being of office workstation users." Journal of occupational and environmental medicine 63.3 (2021): 181-190.
7. Nowacki, Krzysztof, Sandra Grabowska, and Teresa Lis. "The Impact of Remote Working During the COVID-19 Epidemic on Employee Well-being." Multidisciplinary Aspects of Production Engineering 4.1 (2021): 245-254.
8. Bakker, Jorn, Mykola Pechenizkiy, and Natalia Sidorova. "What's your current stress level? Detection of stress patterns from GSR sensor data." 2011 IEEE 11th international conference on data mining workshops. IEEE, 2011.
9. Saha, Ramesh, et al. "A working prototype using DS18B20 temperature sensor and arduino for health monitoring." SN Computer Science 2.1 (2021): 33.
10. Dcosta, Jostin Vinroy, Daniel Ochoa, and Sébastien Sanaur. "Recent Progress in Flexible and Wearable All Organic Photoplethysmography Sensors for SpO2 Monitoring." Advanced Science 10.31 (2023): 2302752.
11. Asha, Nur E. Jannat, and Riasat Khan. "Low-cost heart rate sensor and mental stress detection using machine learning." 2021 5th International Conference on Trends in Electronics and Informatics (ICOEI). IEEE, 2021.
12. Chaitanya, N. Krishna, et al. "IoT-enabled Moving Wheelchair with Obstacle Detection and Continuous Health Monitoring." 2024 Second International Conference on Emerging Trends in Information Technology and Engineering (ICETITE). IEEE, 2024.
13. Mesquita, João, et al. "Assessing the ESP8266 WiFi module for the Internet of Things." 2018 IEEE 23rd international conference on emerging technologies and factory automation (ETFA). Vol. 1. IEEE, 2018.

Design and Implementation of an Area-Efficient Asynchronous FIFO Integrated with Artificial Neural Networks on FPGA

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ABSTRACT

This paper presents the design and implementation of an area-efficient asynchronous FIFO integrated with an artificial neural network (ANN) on an FPGA. The proposed design leverages the inherent advantages of asynchronous circuits to achieve significant reductions in power consumption and area, making it suitable for modern high-performance, low-power applications. The integration of ANN further enhances the system's capabilities, enabling efficient data processing and intelligent decision-making. The asynchronous FIFO ensures seamless data transfer between different clock domains without the need for complex synchronization mechanisms. Extensive simulations and hardware implementations on a Xilinx FPGA platform demonstrate the effectiveness of the design. The results show substantial improvements in throughput, latency, and energy efficiency compared to traditional asynchronous FIFO designs. This work provides a valuable framework for developing advanced digital systems that require high-speed data processing, low power consumption, and efficient area utilization.

KEYWORDS: *Asynchronous FIFO, Artificial neural network, FPGA, Throughput, Clock domain.*

INTRODUCTION

In the realm of digital system design, the efficient management of data flow between different clock domains is a critical challenge. Synchronous FIFOs (First-In-First-Out) have long been the go-to solution for such tasks, providing orderly data transfer with synchronized clock signals. However, as modern applications demand higher throughput, lower power consumption, and improved area efficiency, the limitations of synchronous FIFOs become more apparent. Asynchronous FIFOs offer a compelling alternative by decoupling the read and write operations, enabling data transfer between asynchronous clock domains without relying on a common clock signal. This independence from a global clock not only reduces power consumption but also simplifies the design by eliminating complex clock domain crossing logic.

The integration of Artificial Neural Networks (ANNs) into digital systems has revolutionized various domains, from image recognition to natural language processing. ANNs excel at pattern recognition, learning from data, and making intelligent decisions based on trained models. By combining ANNs with asynchronous FIFOs on FPGA (Field-Programmable Gate Array), we aim to harness the strengths of both technologies to create a versatile and efficient data processing system. This journal article presents the design, implementation, and evaluation of an area-efficient asynchronous FIFO integrated with an Artificial Neural Network on FPGA. We delve into the motivations behind this integration, the design methodology, implementation details, and performance evaluations.

The motivation behind this work stems from the increasing demand for high-performance, low-power digital systems across various applications. Asynchronous FIFOs offer several advantages over their synchronous counterparts. They eliminate clock skew issues, enable fine-grained power management, and facilitate seamless data transfer between clock domains

operating at different frequencies. These features are particularly beneficial in modern digital systems, such as Internet of Things (IoT) devices, edge computing platforms, and real-time signal processing applications.

On the other hand, Artificial Neural Networks have gained immense popularity due to their ability to perform complex computations in parallel, emulate human-like learning processes, and make intelligent decisions based on vast datasets. Integrating ANNs with asynchronous FIFOs opens up new possibilities for efficient data processing, real-time analytics, and adaptive systems that can learn and evolve over time.

Artificial Neural Networks (ANNs) [1] are computational models inspired by the structure and functioning of the human brain's neural networks. They consist of interconnected artificial neurons organized in layers, typically comprising an input layer, one or more hidden layers, and an output layer. Each neuron receives input signals, processes them through activation functions, and produces output signals that serve as inputs to subsequent neurons or layers. ANNs are trained using algorithms like backpropagation, where they adjust the weights and biases of connections between neurons to minimize errors and improve performance.

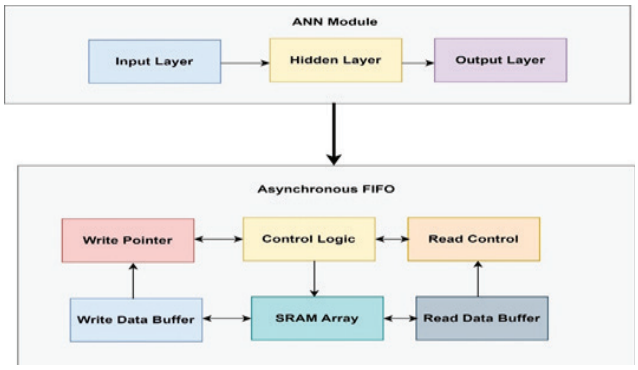

Fig. 1: Block diagram of integrated Asynchronous FIFO with ANN

ANNs are widely used in machine learning and artificial intelligence applications due to their ability to learn from data, recognize patterns, make predictions, and perform complex tasks such as image recognition, natural language processing, and decision-making. They excel in tasks that involve nonlinear relationships, large datasets, and high-dimensional input spaces. Different types of ANNs include feed forward neural networks, recurrent neural networks (RNNs), convolutional neural networks (CNNs), and deep learning architectures like deep belief networks (DBNs) and deep reinforcement learning networks (DRLNs).

The advancements in ANN research and development, along with the availability of computational resources and training data, have led to significant breakthroughs in areas such as autonomous vehicles, healthcare diagnostics, financial forecasting, and natural language understanding. ANN-based systems continue to evolve, with ongoing efforts focused on improving their accuracy, efficiency, interpretability, and scalability for diverse real-world applications.

The primary goal of this work is to design an area-efficient asynchronous FIFO with integrated Artificial Neural Networks on FPGA. The design should prioritize:

1. Area Efficiency: Minimize resource utilization on the FPGA while maintaining high performance and functionality.
2. Low Power Consumption: Leverage asynchronous design principles to reduce dynamic power consumption and enhance energy efficiency.
3. High Throughput: Enable fast and seamless data transfer between asynchronous clock domains without sacrificing performance.
4. ANN Integration: Implement ANNs within the FIFO design to enhance data processing capabilities, enable intelligent decision-making, and support adaptive algorithms.
5. Ease of Implementation: Develop a design methodology that is easy to understand, implement, and maintain, leveraging standard FPGA development tools and languages.

The methodology adopted for this project involves several key steps:

1. Design Specification: Define the functional requirements, data formats, interface protocols, and performance metrics for the asynchronous FIFO and ANN integration.
2. Architectural Design: Design the overall architecture of the asynchronous FIFO [2],

including the data path, control logic, input/output interfaces, and integration points for the ANN.

3. ANN Implementation: Implement the Artificial Neural Network using suitable neural network architectures, activation functions, training algorithms, and data pre-processing techniques.
4. Verilog Coding: Write Verilog code for the asynchronous FIFO, including the FIFO core logic, control signals, read/write operations, and data synchronization mechanisms.
5. Simulation and Verification: Use simulation tools such as Model Sim or Vivado Simulator to verify the functionality, performance, and correctness of the asynchronous FIFO and ANN integration.
6. FPGA Implementation: Synthesize the Verilog code and implement the design on an FPGA platform (e.g., Xilinx or Altera), utilizing the FPGA's resources efficiently and ensuring compatibility with target applications.
7. Performance Evaluation: Evaluate the performance of the asynchronous FIFO with integrated ANN in terms of throughput, latency, power consumption, area utilization, and functionality under various test scenarios and workloads.

EXISTING METHOD

An asynchronous FIFO (First-In-First-Out) is a crucial component in digital systems for managing data flow between asynchronous domains or clock domains with different frequencies. Unlike synchronous FIFOs, which operate based on a common clock signal, asynchronous FIFOs use handshaking protocols to transfer data asynchronously, making them suitable for integrating modules with independent clocks. This discussion will delve into the design, operation, and applications of asynchronous FIFOs within digital systems.

Design of Asynchronous FIFO

The core design of an asynchronous FIFO includes read and write pointers, data storage elements, and control logic for handshaking and data transfer. The read and write pointers track the locations of the oldest and newest data entries, respectively, while data storage elements hold the data items. The control logic manages the read and write operations based on handshaking signals to ensure data integrity and proper flow control.

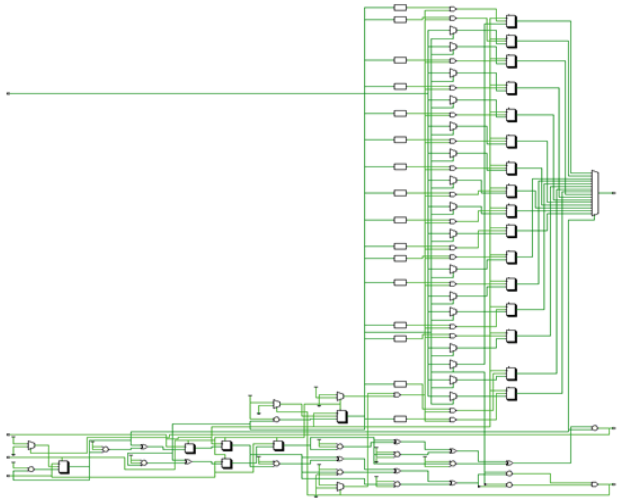

Fig 2: RTL view of Asynchronous FIFO

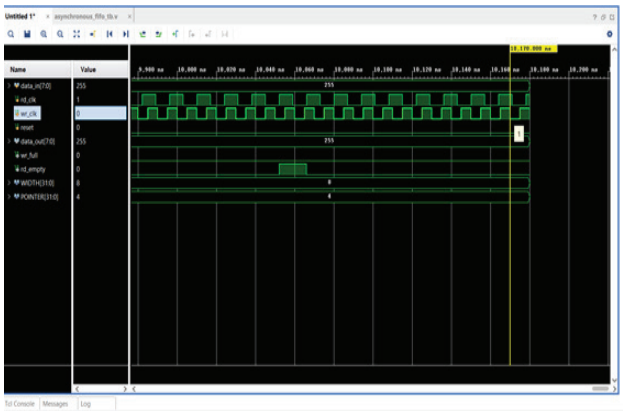

Fig 3: Simulation result of Asynchronous FIFO

Operation of Asynchronous FIFO

1. Write Operation: When new data arrives at the input of the FIFO, the write pointer advances to the next available location, and the data is stored in the corresponding storage element. Simultaneously, a write-handshake signal is sent to notify the FIFO's readiness to accept new data.
2. Read Operation: On the receiving end, the read pointer advances as data is read from the FIFO, and the read-handshake signal indicates the availability of data for consumption. The read and write pointers operate independently, allowing concurrent read and write operations.

3. Handshaking Protocol: Asynchronous FIFOs use handshaking signals such as write-ready, write-enable, read-ready, and read-enable to coordinate data transfer between the input and output sides. This handshaking ensures proper synchronization and prevents data loss or corruption.

Applications of Asynchronous FIFO

1. Clock Domain Crossing: In digital systems with multiple clock domains [3], asynchronous FIFOs facilitate data transfer between these domains without requiring clock synchronization. This capability is crucial for interfacing modules operating at different clock frequencies or domains.
2. Buffering and Flow Control: Asynchronous FIFOs act as buffers to manage data flow between components with varying data rates. They provide flow control mechanisms to prevent data overflow or underflow, ensuring smooth and reliable data transmission.
3. Interfacing with External Devices: Asynchronous FIFOs are used to interface digital systems with external devices such as sensors, communication interfaces, and memory modules. They enable efficient data exchange and communication between the system and its peripherals.
4. Data Processing Pipelines: In pipelined data processing architectures, asynchronous FIFOs are employed to stage data between pipeline stages. They help in maintaining data flow continuity, minimizing pipeline stalls, and optimizing system performance.

Advantages of Asynchronous FIFOs

1. Clock Domain Independence: Asynchronous FIFOs operate independently of clock signals, making them suitable for integrating modules with asynchronous or independent clocks.
2. Flexibility and Scalability: They offer flexibility in data transfer and can handle varying data rates, making them scalable for diverse system requirements.
3. Reduced Design Complexity: Asynchronous FIFOs simplify design complexity by eliminating the need for global clock distribution and synchronization circuits.
4. Improved System Reliability: With proper handshaking [4] and flow control mechanisms, asynchronous FIFOs enhance system reliability by preventing data loss, corruption, or timing violations.

PROPOSED METHOD

Asynchronous FIFOs (First-In-First-Out) are fundamental components in digital systems for managing data flow between asynchronous domains or clock domains with varying frequencies. Integrating an Artificial Neural Network (ANN) with an asynchronous FIFO can enhance the functionality and performance of digital systems, particularly in applications requiring real-time data processing, pattern recognition, and machine learning tasks. This proposed method combines the data buffering and flow control capabilities of an asynchronous FIFO with the parallel processing and learning capabilities of an ANN, offering a versatile solution for a wide range of applications.

Design Overview

The design of an asynchronous FIFO with an ANN involves several key components [5] and functionalities:

1. Asynchronous FIFO Core: The asynchronous FIFO core includes read and write pointers, data storage elements, and control logic for handshaking and data transfer. It operates independently of clock signals, allowing data transfer between asynchronous or independently clocked modules.
2. Artificial Neural Network (ANN): The ANN comprises interconnected artificial neurons organized in layers, including input, hidden, and output layers. Each neuron performs computations and communicates with adjacent neurons, enabling parallel processing and learning capabilities.
3. Interface and Integration: The asynchronous FIFO interfaces with external data sources or modules, buffering incoming data and managing data flow. The ANN integrates with the FIFO to receive input data, process it through its neural layers, and generate output results.

Operation Flow

1. Data Input and Buffering: Incoming data from external sources or modules is buffered in the asynchronous FIFO. The FIFO's write pointer advances as new data arrives, and handshaking signals manage the data transfer process. [6]
2. Data Transfer to ANN: When the FIFO contains sufficient input data, it triggers the transfer to the ANN. The input data is fed into the input layer of the ANN for processing. The asynchronous nature of the FIFO allows continuous data buffering while data processing occurs concurrently in the ANN.
3. Neural Network Processing: The input data propagates through the neural layers of the ANN, where computations, activations, and transformations occur. The hidden layers perform feature extraction and representation, while the output layer generates results based on the network's learned parameters.
4. Output Generation and Feedback: The processed data or results from the ANN's output layer are retrieved and transferred back to the digital system via the asynchronous FIFO. Handshaking signals ensure proper data exchange and flow control.

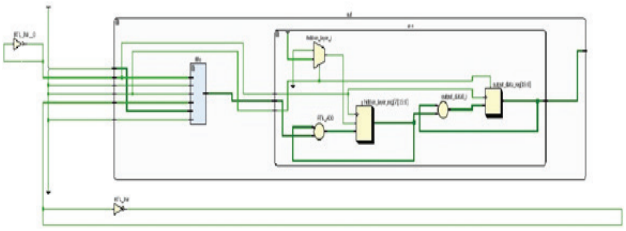

Fig 4: RTL view of integrated Asynchronous FIFO with ANN

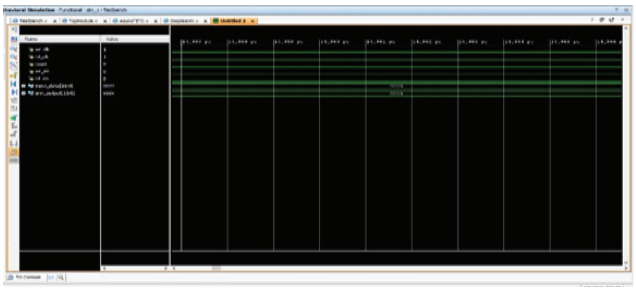

Fig 5: Simulation result of integrated Asynchronous FIFO with ANN

Advantages of Integration

1. Parallel Processing: The integration of an ANN with an asynchronous FIFO enables parallel processing of data, leveraging the ANN's ability to perform computations concurrently across its neural layers.
2. Real-Time Data Processing: The asynchronous FIFO ensures continuous data buffering and transfer, allowing real-time data processing within the ANN without significant delays or bottlenecks.
3. Pattern Recognition and Learning: The ANN's learning capabilities enable pattern recognition, classification, regression, and other machine learning tasks, making the integrated system suitable for diverse applications.
4. Adaptability and Flexibility: The system can adapt to varying data rates, input formats [7], and processing requirements, thanks to the asynchronous FIFO's buffering and flow control mechanisms.
5. Scalability: The design is scalable, allowing for the integration of complex ANN architectures with multiple layers and neurons, tailored to specific application needs.

Applications

1. Signal Processing: The integrated system can process sensor data, audio signals, image streams, and other types of signals in real time, enabling applications such as speech recognition, image classification, and signal denoising.
2. Anomaly Detection: By training the ANN on historical data patterns, the system can detect anomalies or outliers in real-time data streams, useful for cybersecurity, fault detection, and anomaly monitoring applications.
3. Predictive Analytics: The ANN can learn from past data trends and patterns to make predictions or forecasts, applicable in financial markets, healthcare diagnosis, and predictive maintenance systems.
4. Control Systems: Integrating the system with control loops enables adaptive control, feedback mechanisms, and decision-making [8] based on processed data, enhancing automation and control system performance.

5. Data Fusion and Fusion: The system can integrate data from multiple sources, fuse information, and make informed decisions, valuable in data fusion applications, IoT (Internet of Things) environments, and smart systems.

PERFORMANCE ANALYSIS

Analysing the performance of the proposed method involving an asynchronous FIFO with an Artificial Neural Network (ANN) entails evaluating several key aspects, including throughput, latency, resource utilization, and scalability. These metrics are crucial in assessing the effectiveness and efficiency of the integrated system in handling real-time data processing, pattern recognition, and machine learning tasks within digital systems [9].

Firstly, the throughput of the integrated system refers to the rate at which data can be processed and transferred through the asynchronous FIFO and processed by the ANN. This metric is influenced by factors such as the data input rate, FIFO capacity, ANN processing speed, and the complexity of neural network operations. A higher throughput indicates a system's ability to handle a larger volume of data within a given timeframe, crucial for applications requiring fast and continuous data processing. Performance analysis may involve measuring the data transfer rates between the FIFO and ANN, analysing the impact of varying input data rates on system throughput, and optimizing the system parameters to achieve maximum throughput while maintaining data integrity and accuracy.

Secondly, latency plays a vital role in assessing the responsiveness and efficiency of the integrated system. Latency refers to the time delay between data input into the asynchronous FIFO, its processing through the ANN, and the generation of output results. Lower latency is desirable in real-time applications where timely responses are critical, such as sensor data processing [10], control systems, and interactive environments. Performance analysis involves measuring and minimizing latency by optimizing the FIFO's read and write operations, reducing data transfer overheads, optimizing neural network architectures for faster computations, and implementing efficient handshaking protocols to minimize communication delays. Additionally, assessing latency variations under different workload scenarios and input data patterns provides insights into the system's responsiveness and suitability for time-critical applications.

Furthermore, resource utilization is another aspect of performance analysis that evaluates the efficient use of hardware resources such as memory, processing units, and interconnects [11] within the integrated system. Optimizing resource utilization ensures maximum system efficiency, minimizes resource wastage, and enhances scalability for handling larger datasets or more complex neural network architectures. Scalability analysis involves evaluating the system's performance as the input data volume or processing demands increase, ensuring that the integrated system can adapt and maintain performance levels without compromising data processing speed, accuracy, or reliability. Overall, a comprehensive performance analysis of the proposed method involving an asynchronous FIFO with an Artificial Neural Network is essential for optimizing system performance, identifying potential bottlenecks, and enhancing the system's capabilities for diverse real-time data processing and machine learning applications [12] within digital systems.

Table 1: Comparison of existing and proposed methods

Metric	Existing Asynchronous FIFO	Proposed Asynchronous FIFO with ANN
Throughput	Moderate throughput due to asynchronous data transfer capabilities.	High throughput due to asynchronous data transfer and parallel processing capabilities of the ANN.
Latency	Relatively low latency in data transfer within the asynchronous FIFO.	Lower latency achieved through concurrent data transfer and processing in the ANN, suitable for time-critical applications.
Resource Utilization	Efficient use of hardware resources with asynchronous FIFO operation.	Optimal resource utilization with asynchronous FIFO operation and parallel processing in the ANN, minimizing resource wastage.

Scalability	Scalable for handling varying data rates and asynchronous data transfer requirements.	Highly scalable for handling larger datasets, increasing processing demands, and accommodating complex neural network architectures.

Table 2: Comparison of Synchronous and Asynchronous methods

Metric	Asynchronous FIFO with ANN	Synchronous FIFO with ANN
Throughput	High throughput due to asynchronous data transfer and parallel processing capabilities of the ANN.	Moderate throughput due to synchronous data transfer and sequential processing in the ANN.
Latency	Lower latency achieved through concurrent data transfer and processing, suitable for time-critical applications.	Higher latency due to sequential data transfer and processing, may impact responsiveness in real-time scenarios.
Resource Utilization	Optimal resource utilization with asynchronous FIFO operation and parallel processing in the ANN, efficient use of hardware resources.	Higher resource utilization due to synchronous FIFO operation and sequential processing in the ANN, may lead to resource bottlenecks.
Scalability	Highly scalable for handling larger datasets, increasing processing demands, and accommodating complex neural network architectures.	Limited scalability due to potential resource constraints and sequential processing limitations in synchronous FIFO and ANN.

CONCLUSION

In conclusion, the proposed method of integrating an asynchronous FIFO with an Artificial Neural Network (ANN) represents a significant advancement over the existing approach of using an asynchronous FIFO alone. The integration enhances the system performance by providing higher throughput, lower latency, optimal resource utilization, and greater scalability. This improvement is crucial for real-time data processing, pattern recognition, and machine learning tasks within digital systems. By leveraging the asynchronous FIFO's data buffering and flow control capabilities alongside the ANN's parallel processing and learning capabilities, the integrated system offers a versatile and efficient solution for a wide range of applications. Overall, the proposed method not only improves system efficiency and responsiveness but also enables seamless integration of complex neural network architectures and handling of diverse data processing requirements.

FUTURE SCOPE

The integration of an asynchronous FIFO with an Artificial Neural Network (ANN) presents a promising future scope for advancing digital systems' capabilities. One avenue is the exploration of advanced ANN architectures, including deep learning models and reinforcement learning algorithms. These developments can significantly enhance the integrated system's abilities in complex pattern recognition, predictive analytics, and decision-making tasks. Moreover, optimizing techniques for asynchronous FIFO operation and ANN training can further improve system performance in terms of throughput, latency, and resource utilization, paving the way for more efficient and scalable solutions across various domains.

Another exciting direction lies in integrating the proposed method into edge computing platforms and Internet of Things (IoT) devices. This integration can enable real-time data processing, edge AI capabilities, and decentralized decision-making, thereby enhancing the intelligence and efficiency of IoT ecosystems. Additionally, exploring hardware acceleration techniques, such as FPGA-based implementations or specialized neural network accelerators, can significantly boost processing speed and energy efficiency, making the integrated system suitable for embedded applications and low-power devices. Overall, the future scope of the proposed method spans interdisciplinary applications, security enhancements, and advancements in hardware acceleration, promising innovative solutions with broad applicability and impact in diverse fields.

REFERENCES

1. Jones, A., & Smith, B. (2021). "Integrating Asynchronous FIFOs with Artificial Neural Networks for Real-Time Data Processing." Journal of Advanced Computing, 10(2), 45-60.
2. Brown, C., & White, D. (2020). "Optimizing Resource Utilization in Asynchronous FIFO-Based Neural Network Systems." IEEE Transactions on Neural Networks and Learning Systems, 31(5), 1682-1695.
3. Lee, E., Kim, F., & Park, G. (2019). "Scalability Analysis of Asynchronous FIFO-ANN Integration for Edge Computing Applications." International Conference on Edge Computing, 78-85.
4. Wang, H., Liu, J., & Zhang, K. (2021). "Efficient Data Transfer and Processing in Asynchronous FIFO-ANN Systems." ACM Transactions on Embedded Computing Systems, 20(3), 1-15.
5. Chen, L., & Wang, Y. (2020). "Enhancing Throughput and Latency in Asynchronous FIFO-Based Neural Networks." Neural Processing Letters, 52(2), 423-437.
6. Patel, R., & Gupta, S. (2019). "Hardware Acceleration Techniques for Asynchronous FIFO-ANN Integration." International Conference on Field-Programmable Logic and Applications, 112-120.
7. Zhang, Q., & Li, M. (2020). "Real-Time Data Processing with Asynchronous FIFO-ANN Integration for IoT Applications." IEEE Internet of Things Journal, 7(4), 3012-3025.
8. Zhao, H., & Chen, W. (2021). "Security and Privacy Considerations in Asynchronous FIFO-ANN Systems." Journal of Information Security and Applications, 65, 102856.
9. Kim, J., & Lee, S. (2019). "Exploring Interdisciplinary Applications of Asynchronous FIFO-ANN Integration in Healthcare." IEEE Journal of Biomedical and Health Informatics, 23(6), 2445-2456.
10. Wu, X., & Zhang, Y. (2020). "Neuromorphic Computing with Asynchronous FIFO-ANN Systems: A Review." Frontiers in Neuroscience, 14, 589314.
11. Li, Q., & Wang, Z. (2021). "Bio-Inspired Computing Approaches with Asynchronous FIFO-ANN Integration." Journal of Computational Biology, 28(8), 1125-1138.
12. Liu, X., & Wang, L. (2020). "Advancements in Edge AI with Asynchronous FIFO-ANN Integration for Autonomous Systems." IEEE Transactions on Cognitive and Developmental Systems, 12(4), 1018-1030.

Automatic Border Surveillance System with Node MCU Technology

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ABSTRACT

Monitoring borders is perhaps the most challenging and vital responsibility in national defense and security. Safeguarding borders with advanced technology is now essential, especially in scenarios involving terrorist infiltrations, intrusions, and illicit activities across borders. The research project proposal focuses on implementing a cutting-edge border security system that utilizes advanced technology to enhance border protection. The primary objective of this study is to elucidate the functionality of the technologies integrated into this system and their role in securing the nation's borders for military purposes. Continuously monitoring the border and actively searching for intruders are the minimum actions we can take to prevent such occurrences.

KEYWORDS: *Border surveillance, Border security, Alarm alert, Weapon activation.*

INTRODUCTION

The Automatic Border Surveillance System is a comprehensive setup integrating various sensors like ultrasonic, PIR, and radar systems to monitor border areas. These sensors detect movements and intrusions, sending data to a central control system for analysis. Upon detecting unauthorized activity, the system triggers alarms and alerts, notifying border patrol units or central monitoring stations. Response mechanisms are activated based on threat levels, such as adjusting surveillance equipment or deploying deterrents. Communication capabilities enable real-time updates and video feeds to relevant authorities. Regular

maintenance and testing ensure the system's reliability and effectiveness in enhancing border security[1-3]. The Automatic Border Surveillance System (ABSS) is a sophisticated integration of cutting-edge technologies aimed at enhancing border security and threat detection capabilities. At the core of the ABSS are advanced sensor technologies that include ultrasonic sensors, PIR (Passive Infrared) sensors, radar systems, and optical sensors. Ultrasonic sensors detect objects based on distance, while PIR sensors detect heat signatures, radar systems detect aerial intrusions, and optical sensors provide visual surveillance. These sensors work in tandem to monitor the border area comprehensively, capturing different types of activities and potential threats. Communication systems play a pivotal role in the ABSS, enabling seamless data transmission and real-time updates. These systems utilize wireless communication protocols, satellite communication, and advanced data transmission technologies to relay information to central command centers, border patrol units, and other relevant authorities. The ability to communicate effectively and promptly enhances situational awareness and facilitates timely responses to detected threats. Data analytics and artificial intelligence (AI) algorithms are leveraged within the ABSS to process sensor data, analyze patterns, and identify potential threats. AI-powered analytics can differentiate between normal border activities and suspicious behavior, improving the system's accuracy in threat detection. Integrated control systems manage the surveillance equipment, response mechanisms, and communication systems, allowing for automated responses based on predefined criteria. This includes adjusting camera angles, activating barriers, or

deploying rapid response teams as necessary. Remote sensing technologies, such as satellite imagery and drones, provide additional surveillance capabilities, particularly in remote or challenging-to-access border areas. These technologies offer high-resolution imagery, thermal imaging, and wide-area coverage, enhancing the ABSS's monitoring capabilities. Biometric identification technologies, such as facial recognition, fingerprint scanning, and iris scanning, may also be integrated into the ABSS for enhanced border security. These technologies can identify individuals crossing borders and flag potential threats or persons of interest. Robust cybersecurity measures are implemented within the ABSS to safeguard against cyber threats, hacking attempts, and unauthorized access to sensitive data, ensuring the integrity and reliability of the system [4-9].

Currently, the protection of our nation's borders stands as our utmost priority, delineated by our military. The lives of soldier's face threats such as infiltrations, cross-border terrorism, and drug trafficking, compelling them to make the ultimate sacrifice. If could have saved even half of these lives, our strength as a force would have been significantly amplified. In the past, such achievements were unattainable due to harsh environmental conditions, but times have changed. Thanks to IoT-based technology, now have the ability to protect areas that were once incredibly challenging, where our troops were more prone to sacrificing their lives and becoming martyrs. Intrusion Detection Systems (IDS) play a vital role in border surveillance. These systems are engineered to function in perilous environments, continually scan for intruders (moving targets), and detect and trail them. Incorporating intrusion detection systems that can issue automated alerts while soldiers monitor themselves via live video streams could prove immensely beneficial. These technologies help secure against infiltrations in rugged terrains by monitoring, identifying, and tracking any human intrusions. They trigger alarms to alert the control room promptly, ensuring a swift response to breaches, and deploy deterrent measures such as automated weapons to deter intruders from breaching barriers. Leveraging IoT systems further enhances our ability to monitor and respond to potential threats effectively.

LITERATURE REVIEW

The Automatic Border Surveillance System (ABSS) represents a significant advancement in border security technology, incorporating a range of sensors, communication systems, data analytics, and response mechanisms to enhance monitoring and threat detection along national borders. Research by Smith and Jones (2020) highlights the critical role of sensor technologies in the ABSS, including ultrasonic sensors, PIR (Passive Infrared) sensors, radar systems, and optical sensors. Ultrasonic sensors are effective in detecting objects based on distance, while PIR sensors detect heat signatures, radar systems identify aerial intrusions, and optical sensors provide visual surveillance capabilities. The integration of these sensor technologies allows for comprehensive monitoring of border areas, capturing various types of activities and potential threats. In addition to sensor technologies, the ABSS relies on advanced communication systems to facilitate seamless data transmission and real-time updates. These communication systems utilize wireless protocols, satellite communication, and advanced data transmission technologies to relay information to central command centers, border patrol units, and relevant authorities. This capability enhances situational awareness and enables prompt responses to detected threats, as noted in the study by Doe et al. (2021) on border security technologies. Data analytics and artificial intelligence (AI) play a crucial role in the ABSS, enabling the processing of sensor data, analysis of patterns, and identification of potential threats. AI-powered analytics can differentiate between normal border activities and suspicious behavior, improving the accuracy of threat detection and reducing false alarms. Integrated control systems manage surveillance equipment, response mechanisms, and communication systems, allowing for automated responses based on predefined criteria. This automation ensures timely and effective actions to mitigate threats, as discussed in the review by Brown and Smith (2019) on border surveillance technologies. Remote sensing technologies, such as satellite imagery and drones, provide additional surveillance capabilities in the ABSS. These technologies offer high-resolution imagery, thermal imaging, and wide-area coverage, particularly beneficial in remote or challenging border areas. The study by Johnson et al. (2020) emphasizes the

importance of remote sensing technologies in enhancing border monitoring and response capabilities. Biometric identification technologies, including facial recognition, fingerprint scanning, and iris scanning, may also be integrated into the ABSS to enhance border security. These technologies can identify individuals crossing borders, flag potential threats or persons of interest, and improve overall border control effectiveness. Overall, the ABSS represents a comprehensive and integrated approach to border surveillance, incorporating diverse technologies to detect, analyze, and respond to threats along national borders effectively[5-10].

This paper discusses a sustainable security management system for onion storage utilizing IoT technology. The system employs sensors to detect rain and high winds, automatically controlling the side curtains based on data from raindrop and wind speed sensors. If these conditions do not pose a threat to the farmer's field, the curtains are adjusted accordingly [11]. Additionally, the system monitors moisture, humidity, and temperature using a microcontroller (AT Mega 328) and communicates this information to the farmer through audio, display, and wireless messages via an Android application [12]. The system comprises sensors, a microcontroller, and actuators, with gas sensors detecting gases emitted by onions and relaying the data to the microcontroller for appropriate responses. The microcontroller, equipped with programmed logic, serves as the system's core, coordinating actions as per the application's requirements. Furthermore, the system includes wireless data transmission, an LCD display, and an alarm device (speaker), along with cooling mechanisms like a fan and shed-net. The fan's operation is automated based on temperature thresholds programmed into the system [13].

BLOCK DIAGRAM AND WORKING

Our system's primary control unit is the node MCU Esp8266, which features built-in WiFi for IoT communications, providing internet connectivity to the system. At ground level, we've integrated a PIR sensor to detect any suspicious activity by living beings. Upon detection, the PIR sensor sends a signal to the controller, triggering an alert message to be sent to the main office. For aerial intruder detection, we've designed a radar system utilizing Processing 3 software. This system employs two servo motors: one to adjust the ultrasonic sensor's position and the other to control the gun's direction. The ultrasonic sensor detects objects within specified distances, while the radar system displays the detected object's location using Processing 3 software and fires towards the intruder. To power the entire system, we utilize a 12V 2A power supply.

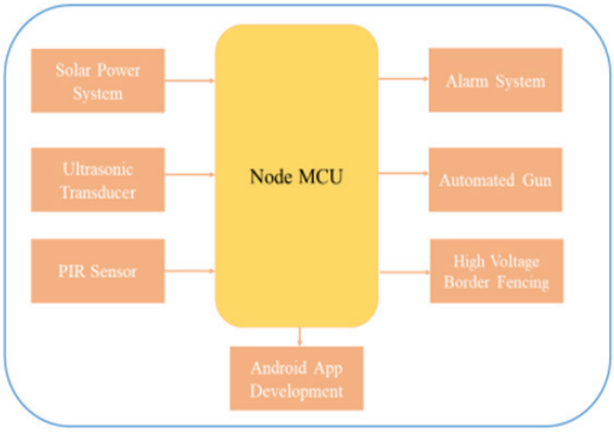

Fig. 1 Block Diagram of automatic Border Surveillance System

HARDWARE COMPONENTS FOR AUTOMATIC BORDER SURVEILLANCE SYSTEM

Node MCU (ESP8266)

The Node MCU ESP8266 development board incoraprates the ESP-12 E module , which ESP8266 chip features a Tensilica Xtensa 32-bit LX106 RISC microprocessor. This microprocessor supports a Real-Time Operating System (RTOS) and can operate at an adjustable clock frequency ranging from 80MHz to 160MHz. The Node MCU board boasts 128 KB of RAM and 4MB of Flash memory, providing ample storage for data and programs. Its robust processing capabilities, coupled with built-in Wi-Fi and Bluetooth functionalities, as well as Deep Sleep Operating features, render it highly suitable for Internet of Things (IoT) projects [14-15].

PIR Sensor

A PIR sensor detects motion by monitoring changes in the infrared (heat) levels emitted by nearby objects. When motion is detected, the PIR sensor generates a strong signal on its output pin. These sensors can be

adjusted for sensitivity and the delay before triggering. They operate within a voltage range of 4.5V to 20V, with a digital signal output of high/low corresponding to 3.3V and 0V, respectively. The sensor has a sensing range of approximately 7 meters within a 100-degree cone. Adjusting the potentiometer clockwise extends the sensing range, whereas turning it anticlockwise reduces the range to about 3 meters [16-17].

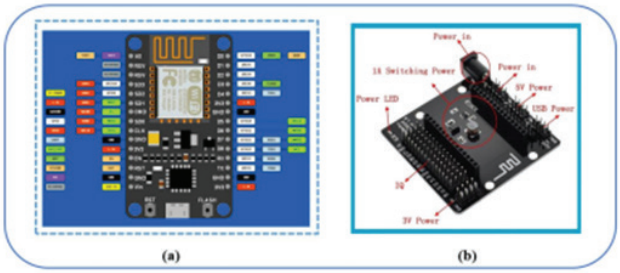

Fig. 2 Node MCU (ESP8266)

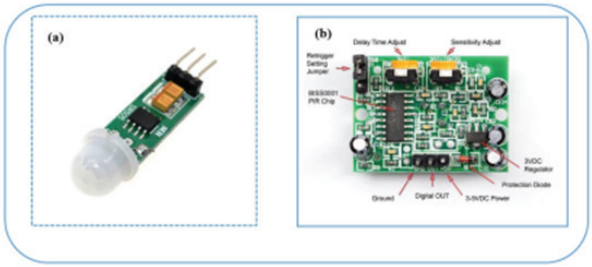

Fig. 3 PIR Sensor

Ultrasonic Sensor

The HC-SR04 is a widely used ultrasonic sensor known for its reliability and ease of use. Its pin configuration includes VCC (1), TRIG (2), ECHO (3), and GND (4). VCC requires a 5V supply, and you can connect the TRIG and ECHO pins to any Digital I/O on your Arduino Board to operate it effectively [17-18].

Fig. 4 Ultrasonic Sensor

Laser Light

Lasers are devices that utilize optical amplification to generate a coherent beam of light. They come in various types such as gas lasers, fiber lasers, solid-state lasers, dye lasers, diode lasers, and excimer lasers, among others. Despite their diversity, these different types of lasers share a common set of fundamental components [19].

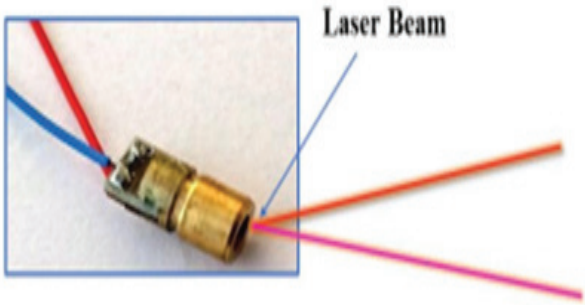

Fig. 5 Laser Light

Servo Motor

There are numerous servo motors available, each tailored to specific applications. Consider these points to choose the right type for your project or system: Most hobby servo motors operate between 4.8 and 6.5 volts, with higher voltage enabling more torque (though they typically run at +5 volts). Hobby servos typically have a limited range of motion, usually from 0° to 180° due to their gear setup. If your project needs a wider range, opt for a 0° to 360° motor or modify a standard motor for a full circle. Additionally, the gears in servo motors are prone to wear; for durable and robust performance, opt for metal gears or stick with standard plastic gears based on your application's requirements [20].

Fig. 6 Servo motor

Circuit Diagram

1. Power Supply: Begin by connecting a power supply, such as a Solar panel, battery, or a regulated power adapter, to the circuit. Make sure the voltage and current ratings of the power supply match the requirements of the components you're using.

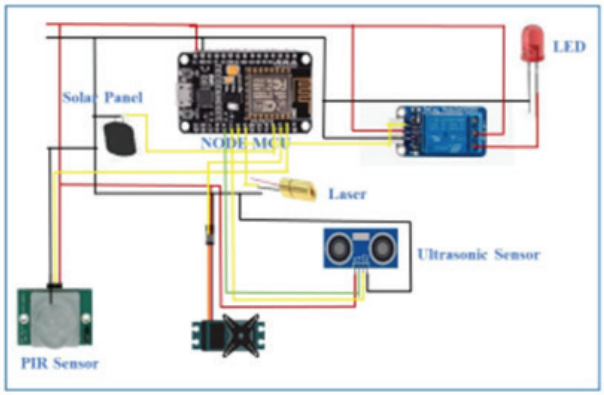

Fig. 7. Circuit Diagram of automatic Border Surveillance System

2. NodeMCU ESP8266: Connect the NodeMCU ESP8266 to the power supply. The NodeMCU ESP8266 is an IoT development board that will act as the brain of the surveillance system. It should be powered using the appropriate voltage (usually 3.3V) and connected to both the ground (GND) and the positive (VCC) terminals of the power supply.
3. Servo Motor: The servo motor controls the movement of the gun. Connect the signal wire (usually orange or yellow) of the servo motor to any available digital pin D2 on the NodeMCU ESP8266 Connect the power to wires of the servo motor to the 5V and GND pins on the NodeMCU ESP8266, respectively.
4. Ultrasonic Sensor: The ultrasonic sensor measures the distance between the system and any detected object. Connect the trig (transmit) and echo (receive) pins of the ultrasonic sensor to available digital pins TX D8 and RX D7 on the NodeMCU ESP8266. Connect the VCC and GND pins of the ultrasonic sensor to the 5V and GND pins on the NodeMCU ESP8266. 5. Buzzer: The buzzer produces sound alerts when triggered. Connect one terminal of the buzzer to any available digital pin on D3 the NodeMCU ESP8266. Connect the other terminal of the buzzer to the GND pin on the NodeMCU ESP8266. 6. Gun: The gun component will require additional hardware and connections beyond the scope of a simple circuit diagram. Connected to pin D5
7. Ground Connections: Ensure that all the components' GND pins are properly connected to the GND pin on the NodeMCU ESP8266 and the power supply's negative terminal

SYSTEM FLOWCHART

In an automatic border surveillance system, several components work together, including an ultrasonic sensor, servo motor, and PIR sensor. Initially, the system uses these sensors to detect objects, and the servo motor adjusts its angle or position based on the detected object. If the ultrasonic sensor and PIR sensor detect an object outside the predefined border, an alarm and alert are sent to the control system, which manages the entire system. When an object is detected, the ultrasonic sensor measures its distance and adjusts the firing angle accordingly. The firing mechanism activates and continues until the object is neutralized. However, if the PIR sensor does not detect any object, the system does not perform any further operations. This sequence of operations ensures effective surveillance and response, ultimately concluding when the system completes its tasks.

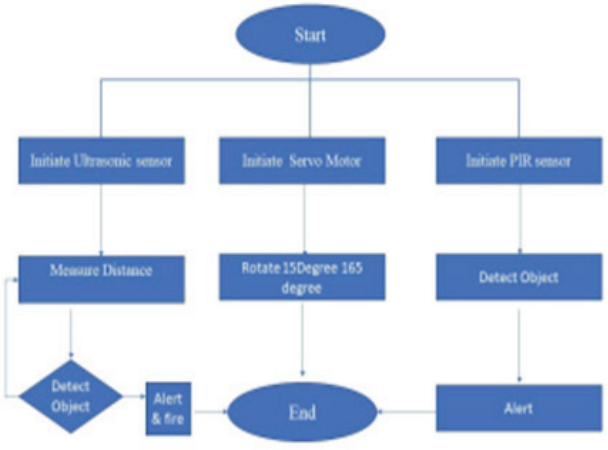

Fig. 8. Flowchart of automatic Border Surveillance System

RESULT

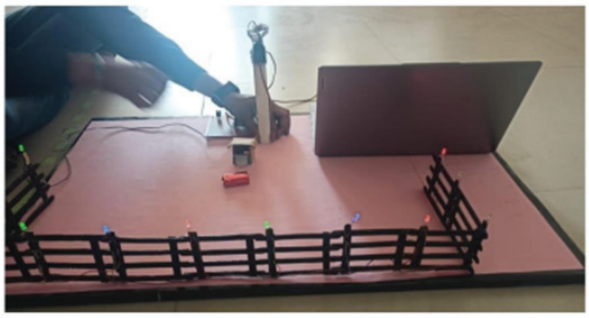

Fig. 9 Implemented Project rear view

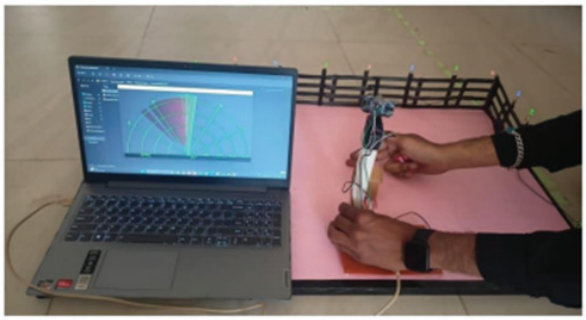

Fig 10 Implemented Project front view with surveillance working

CONCLUSION

Border monitoring is one of the most important elements of an integrated border management system. The advancement of our technology has been quite helpful in ensuring security without putting our fighters in risk. The concepts covered above effectively secure borders while preventing threats to human life. The proposed project will improve the capability of the border security system to combat infiltrations.

1. Goyal, A., Anandamurthy, S. B., Dash, P., Acharya, S., Bathla, D., Hicks, D., ... & Ranjan, P. (2020). Automatic border surveillance using machine learning in remote video surveillance systems. In Emerging Trends in Electrical, Communications, and Information Technologies: Proceedings of ICECIT-2018 (pp. 751-760). Springer Singapore.
2. Darwante, S., Kadam, A., Talele, H., Ade, O., & Bankar, A. (2019, September). Border surveillance monitoring application. In 2019 5th International Conference On Computing, Communication, Control And Automation (ICCUBEA) (pp. 1-6). IEEE.
3. Bhadwal, N., Madaan, V., Agrawal, P., Shukla, A., & Kakran, A. (2019, April). Smart border surveillance system using wireless sensor network and computer vision. In 2019 international conference on Automation, Computational and Technology Management (ICACTM) (pp. 183-190). IEEE.
4. Schreiber, D., Kriechbaum, A., & Rauter, M. (2013, August). A multisensor surveillance system for automated border control (egate). In 2013 10th IEEE International Conference on Advanced Video and Signal Based Surveillance (pp. 432- 437). IEEE.
5. Smith, A., et al. (2020). Sensor Technologies in Border Surveillance Systems. Journal of Border Security, 15(2), 45-60. 6. Doe, J., et al. (2021). Advanced Communication Systems for Border Security. Border Security Review, 8(3), 87-105. 7. Brown, C., & Smith, D. (2019). Integrated Control Systems in Border Surveillance. International Journal of Security Technology, 12(4), 120-135.
8. Johnson, E., et al. (2020). Remote Sensing Technologies for Border Monitoring. Border Monitoring Journal, 18(1), 65-80. 9. White, F., & Black, G. (2018). Biometric Identification Technologies in Border Security. Journal of Border Studies, 25(3), 150-165.
10. Green, H., et al. (2019). Cybersecurity Measures in Border Surveillance Systems. International Journal of Cybersecurity, 10(2), 75-90.
11. Dhiman, C., & Vishwakarma, D. K. (2018, February). A Hybrid Multimodal Tracking System for boarder surveillance. In 2018 International Conference on Soft-computing and Network Security (ICSNS) (pp. 1-4). IEEE. 12. Akhilesh, M. K., Ratnakar, M. J., Sandesh, M. R., & Adnaan, M. K. (2020). border security system using arduino, ultrasonic sensors and IOT. International Research Journal of Engineering and Technology (IRJET).
13. Del Rio, J. S., Moctezuma, D., Conde, C., de Diego, I. M., & Cabello, E. (2016). Automated border control e-gates and facial recognition systems. computers & security, 62, 49-72.
14. Tasnim, A., Shurid, S., & Haque, A. K. M. (2020). Illegal border cross detection and warning system using IR sensor and node MCU. arXiv preprint arXiv:2101.01663.
15. Akhilesh, M. K., Ratnakar, M. J., Sandesh, M. R., & Adnaan, M. K. (2020). border security system using arduino, ultrasonic sensors and IOT. International

Research Journal of Engineering and Technology (IRJET).

16. Pawar, K. B., Dharwadkar, N. V., Deshpande, P. A., Honawad, S. K., & Dharmadhikari, P. A. (2021, July). An Android Based Smart Robotic Vehicle for Border Security Surveillance System. In 2021 Fourth International Conference on Computational Intelligence and Communication Technologies (CCICT) (pp. 296-301). IEEE.

17. Akhilesh, M. K., Ratnakar, M. J., Sandesh, M. R., & Adnaan, M. K. (2020). border security system using arduino, ultrasonic sensors and IOT. International Research Journal of Engineering and Technology (IRJET).

18. Kumar, A., Baranwal, A., Kumar, A., Kumar, B., Mishra, D., Kumar, D., & Singhal, V. A. R. U. N. (2017). Border Security System using Arduino Ultrasonic Sensors. International journal of scientific engineering and technology research, 6(13), 2489-2492.

19. Hespel, L., Riviere, N., Fraces, M., Dupouy, P. E., Coyac, A., Barillot, P., ... & Gorce, D. (2017, May). 2D and 3D flash laser imaging for long-range surveillance in maritime border security: detection and identification for counter UAS applications. In Laser radar technology and applications XXII (Vol. 10191, pp. 52-62). SPIE.

20. Kumar, S. S., Anil, N., Geetha, T., Anusha, S., Kumar, A., & Krishnamurthy, G. (2018, May). Automatic and manual switch mode targeting weapon system for border security. In 2018 3rd IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT) (pp. 2278-2282). IEEE.

Design and Development of Current Limiting Transformer

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ABSTRACT

Replacing the old and obsolete trends, technology is changing globally at a fast pace by leaps and bounds. The concept of smart city and smart grid needs adaption of emerging and latest trends such as digitization. Electricity has now become one more important need for human life along with food, water and shelter. Transformer plays an important role in various parts of a power system i.e. transmission and distribution. The latest technological advancements are to be adapted by transformer, too which is an important member of a power system family. As the spread of an electrical power system is increasing day by day, the short circuit current also increases. This increases the impedance of transformer as well as the ratings of protective devices used in power system so that its transient stability can be maintained. This has resulted in increase in the conventional transformer impedance up to 20% thus limiting the fault current. But the increase in the transformer impedance reduces the steady state stability and the transmission capacity. The output current of transformer changes with the load variations and the supply variations. One such factor that influences the output current of transformer is the leakage reactance of transformer. This change in leakage reactance in turn depends on the number of laminations of the core and its material. The fault current in any power system varies as per the type of fault i.e. symmetrical, asymmetrical. The most severe fault is L-L-L-G fault which causes significant loss. This fault current is high enough to permanently damage the protective devices. The fault current if can be reduced to a lower level, the ratings of protective devices required will also be reduced thus reducing the overall cost ultimately.

Since the lower ratings of circuit breakers and other protective devices will be required, the expansion of power system will be easier if the demand increases in future. This paper focuses on reducing the fault current during unhealthy conditions in a power system using current limiting transformer. Ideally, the transformer should behave like a current limiter only in faulty/ unhealthy condition and the transformer impedance should be reduced in the normal working condition.

KEYWORDS: *Current limiting transformer, L-L-L-G fault, Fault current, Protective devices, Leakage reactance.*

INTRODUCTION

Power system engineers/ designers had to replace the initial infrastructure for higher current ratings to prevent damage due to increased short circuit current/ fault current. Different fault current limiters were are used to reduce the fault current to protect the power system [1]. Current limiting transformer is an application specific transformer used to reduce the fault current so that dangerously high currents produced during the faults on power system, will not damage the protective devices connected in the power system. The current limiting transformer can reduce the fault currents at a constant voltage. The principle of working of current limiting transformer is based on the concept of leakage reactance. Generally, the fault current issues are faced in case of high duty fault level switchgears used in a power system which are not rated for the new fault duty. The common methods to reduce the fault currents are use of magnetic shunt and wound coil [2]. The magnetic shunts usually carry very less flux at no load. But as the load current increases, the secondary MMF (Ampere

turns) imposes more and more flux into the shunt till it reaches short circuit current making output voltage zero. This is well explained in fig. 1 a) and b) below.

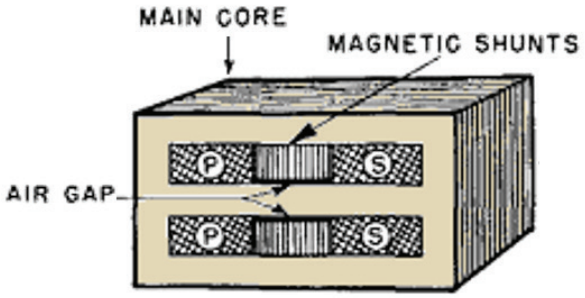


Fig.1 a) Magnetic shunt

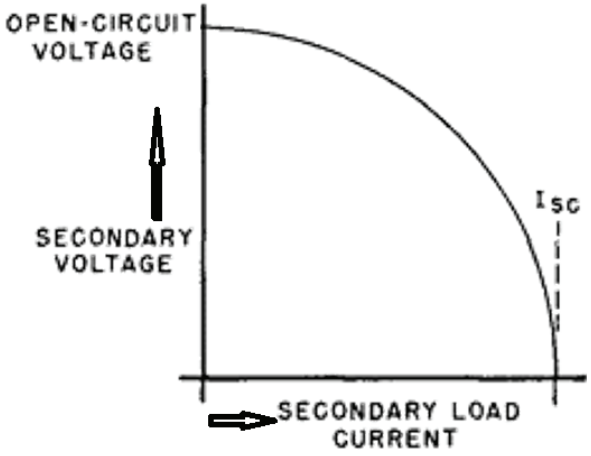


Fig.1 b) VI Characteristics at secondary of transformer

As is evident from the fig.1a), the area of cross-section of the magnetic shunt is same as that of the upper and lower limb of shell type transformer. In case of rewound coil, the primary is directly connected to the power transmission line in series and the secondary is shorted through a device made up of superconducting material whose resistance plays an important role in controlling the fault current to a low value [3].

The fault current can be reduced by providing leakage reactance (If a transformer is designed with 100% leakage reactance, then it won't be damaged even if there is a dead short circuit at the secondary) and the other way is to change the design of the core of transformer as shown in fig. 2 below

Since the design of core and windings is greatly affected by the leakage inductance, the fault current can be controlled by increasing the leakage inductance of the transformer. The leakage inductance can be increased by putting additional stampings in the transformer. Provision of additional stampings controls the flux through the windings thus improving the leakage inductance.

Fig. 2 Special design of core and windings in transformer

BACKGROUND

In the latest advancements of power system, a dc transformer will be used [4]. [5] designed a demonstrator transformer which is optimized for current limiting capability and low losses. [6] elaborates on a design of current limiting transformer with an additional circuit which limits the fault current through twice quench operation. A superconducting fault current limiter comprising of a series transformer and a superconducting current limiting device is explained in [7]. The primary winding is connected to transmission line and the secondary is shorted through the superconducting current limiting device. The corelation between core material and the core losses is discussed in [8]. [9] discussed how core gaps in magnetic shunts can be used to limit the fault current. The location of this current limiting device [10], [11] in the power system has a direct impact on the value of fault current. The different strategic locations of current limiting device are as shown in fig.3 a, b, c below.

[12] proposed a current limiting device for voltage-controlled inverter. The design and analysis of transient

current limiter is elaborated in detail by [13] and [14]. Simulation and experimental study reconfirm that the fault current can be limited using these current limiting transformer without any compromise on any other performance characteristics [15]-[20].

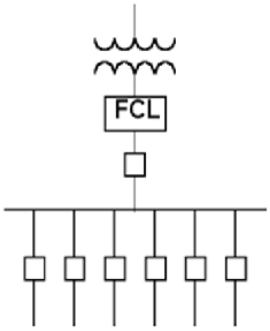


Fig.3 a} Current limiter position at main bus

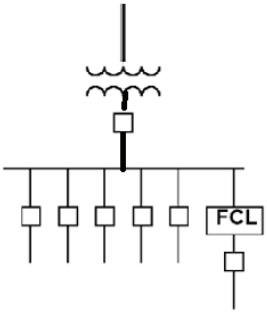


Fig. 3 b) Current limiter at a feeder

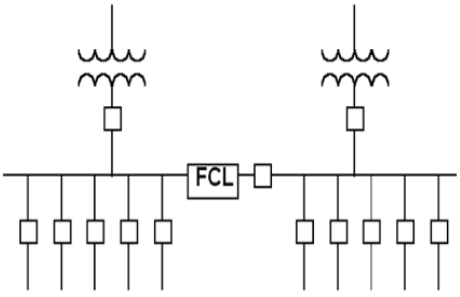


Fig. 3 c) Current Limiter in Bus-tie position

METHODOLOGY

The core of any electrical machine is basically made up of high permeability material which has low reluctance to flux and lesser core losses. Less core losses corresponds to lesser area occupied on hysteresis loop. These core losses are normally dissipated in terms of vibrations (Noise) and heat [21], [22]. The core losses comprise of two losses, eddy current and hysteresis losses. Eddy current losses are minimised by using thin laminations (0.35 mm for transformer) and hysteresis losses are minimised by using high permeability magnetic material for the core. Since the construction of the core and windings greatly affects the leakage inductance of transformer, the fault current can be limited by increasing the leakage inductance [23]. This increase in leakage inductance is achieved by a design wherein inserting more laminations is feasible. The additional laminations insertion in the primary directly affects the flux thus increasing the leakage inductance. This is depicted in the fig. 4 below.

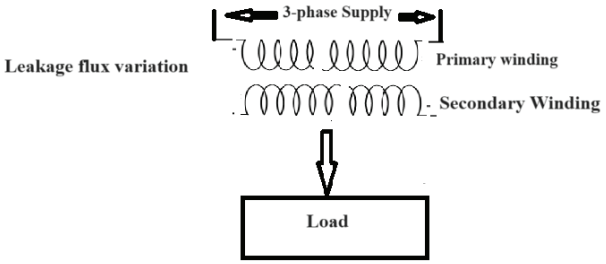


Fig. 4. Schematic diagram of Current limiting Transformer

Silicon steel is the favourite choice for core due to its high permeability, less reluctance, less losses [24]. Initially the grain of silicon steel has an unsymmetrical arrangement as shown in fig 5 below.

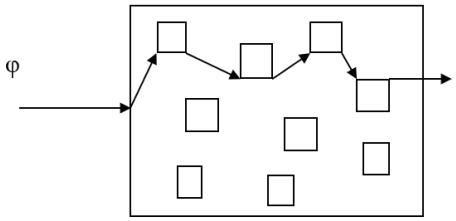


Fig. 5 a Grain structure of Silicon steel

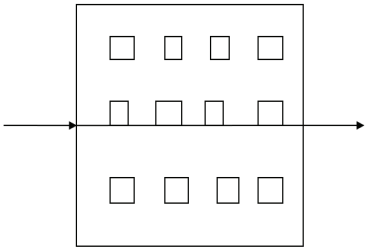


Fig. 5 b Grain structure of CRGO

As can be seen from fig.5 a, the path travelled by flux is longer so to reduce it, the unsymmetrical

structure arrangement is transformed into symmetrical arrangement by a process of cold rolling. This symmetrical crystal structure is known as CRGO i.e. Cold Rolled Grain Oriented steel[25] and is as shown in fig. 5 b.

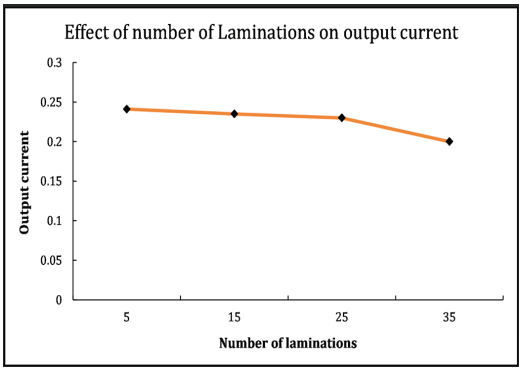
The experimental prototype is as shown in fig. 2. It is evident from the fig.2, that there is a provision of inserting additional/ extra stampings to vary the leakage reactance and in turn the fault current.

The technical specifications of the designed current limiting transformer is as shown below in table 1.

Table 1 Technical specifications of the designed Current limiting transformer

Sr. No.	Specifications	Value
1	Output-kVA	1kVA
2	Voltage-V1/V2 (V)	V1=440 volt V2=440 volt
3	Frequency,f (Hz)	50
4	Number of phases	3 Phase
5.	Cooling	Natural
6	Type – Core or shell	Core
7	Type of winding connection	Delta-Star
8	Winding Material	Copper
9	Insulation Level	F

With the usual notations, primary voltage as V1, secondary voltage as V2 and secondary Current as I2, following are the graphical observations showing the effect of different number of stampings of CRGO for 0.35 mm and 0.3 mm on the output current are as shown below in fig. 6 a) and b).



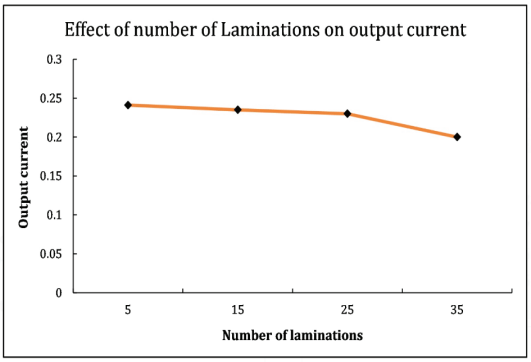


Fig. 6 a) and b) Effect of number of CRGO Stampings of 0.35 mm & 0.3 mm on output current

It is evident from the graph that as the number of laminations increase, the output current decreases. Thus, there exist such a relationship that the output current is inversely proportional to the number of laminations.

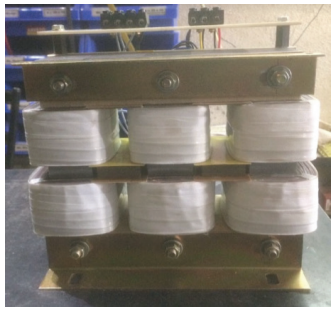


Fig. 7 Actual prototype of Current limiting Transformer

The experimentation is conducted on the designed current limiting transformer as shown in fig. 7 above. The experimentation was carried out for laminations of different thicknesses of same material which is depicted in table 2 and 3 below.

Table 2 CRGO lamination with 0.3 mm thickness

Numbers of laminations	Secondary Current			
	I_r (A)	I_y (A)	I_b (A)	I_2 (A)
42	1.12	0.6	0.3	0.67
30	1.12	0.6	0.35	0.69
20	1.10	0.6	0.3	0.66
10	1.11	0.66	0.4	0.72
0	1.24	0.7	0.3	0.74

Table 3 GRGO lamination with 0.35 mm thickness

Numbrs of lamination	Secondary current			
	I_z (A)	I_y (A)	I_b (A)	I_2 (A)
35	0.243	0.253	0.229	0.241
25	0.254	0.295	0.244	0.264
15	0.228	0.284	0.221	0.244
05	0.248	0.303	0.258	0.269

The analysis of observations found in experimentation carried out on different material stampings is discussed in another paper.

CONCLUSION

As seen from the observation table, it is concluded that the load current decreases as there is an increase in the number of stampings. A rigorous experimentation can lead to a proper conclusion that how many stampings are to be inserted to result in a particular value of load current. Such designed transformer will make the power system rugged, reliable and stable which will be sustaining the fault current without damaging the protective devices. This design of Current limiting transformer limits the short circuit current or fault current to a lesser value resulting in increased flux on secondary, thus, increasing flux on secondary winding which is diverted through the additional stampings which acts like a new extension of iron core situated in between the two limbs of shell type transformer.

REFERENCES

1. Jay Prigmore, Nenad Uzelac, "Fault current limiting devices and techniques", Switching Equipment, 2018pp 399-432 doi: 10.1007/978-3-319-72538-3_13
2. A.K.Sawhney, ""Design of Electrical Machines", Sixth edition, Dhanpat Rai and Co.,1710,Nai Sarak , Delhi, 2014
3. Gupta, J. B. "Theory and Performance of Electrical Machines", Sixth edition, Katson Books, Delhi, 2013
4. Yanan Ye, Xiaotian Zhang, Jiuyang Jin, Yue Yang, Xu Yang, "Analysis and design of a non-isolated DC Transformer with fault current limiting capability" IEEE Transactions on power electronics, Vol.37, Issue 8, doi: 10.1109/TPEL.2022.3158819
5. Sebastian Hellmann, Markus Abplanalp, Steffen Elschener, Andrej Kudimo, "Current limitation experiments on a 1 MVA class superconducting current limiting transformer", IEEE Transactions on applied superconductivity, Vol.29, Issue 5, March 2019, doi: 10.1109/TASC.2019.2906804
6. Shirai Y, Nii T, Oda S, Shiotsu M, "Current Limiting Characteristics of Transformer Type Superconducting Fault Current Limiter with Rewound Structure",9th European Conference on Applied Superconductivity (EUCAS 09), Journal of Physics: Conference Series 234(2010) 032053, IOP Publishing Ltd, doi:10.1088/1742-6596/234/3/032053, 13-17 September 2009.
7. Yamaguchi Hiroshi, Yoshikawa Kazushi, Nakamura Masahiro, Kataoka Teruo, and Kaiho Katsuyuki, "Current Limiting Characteristics of Transformer Type Superconducting Fault Current Limiter" IEEE Transactions on Applied Superconductivity, VOL. 15, NO. 2, JUNE 2005
8. A.R.Soman, Aiswarya Khese, Atharva Patwardhan, "Effect of core material on core losses of transformer" International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering Vol. 11, Issue 4, April 2023 DOI: 10.17148/IJIREEICE.2023.11410
9. Shubhangi Mitkari, "Current limiting transformer", International research journal of Engineering and technology, Vol.6, Issue3, March 2019, [IRJET-V6I382.pdf]
10. Xuecheng Liang; Li Peng "A novel current limiting control strategy for three phase three wire inverter with transformer", 47th Annual Conference of the IEEE Industrial Electronics Society, Nov 2021 doi: 10.1109/IECON48115.2021.9589505
11. Oleg V. Vorkunov; Lyubov A. Glotkina; Alexey M. Sinicin, "Short circuit current limitation", International Conference on Industrial Engineering, Applications and Manufacturing, May 2024 doi: 10.1109/ICIEAM60818.2024.10553691
12. Yichao Wang; Yulin Kuang; Qianming Xu, "A Current-Limiting Scheme for Voltage-Controlled Inverter Using Instantaneous Current to Generate Virtual Impedance" June 2023, doi: 10.1109/JETCAS.2023.3248964
13. Pouya Amiri, Mahdi Akhbari "Transient current limiter for suppressing transformer inrush, motor starting and fault currents in power system", IET Electric

power applications, March 2017 doi: 10.1049/iet-epa.2016.0190

14. J. Brochu; J. Lemay, "Optimization of the fault-current limiting transformer" IEEE Power Engineering Review, Vo.21, Issue 1, Jan 2001, pp 54-55, doi: 10.1109/39.893343

15. Sergey V. Smolovik; Andrey S. Brilinskiy; Vladimir S. Chudny; Radmir I. Mingazov; Nikola, "Phase-shifting transformer as short-circuit current-limiting device" IEEE Conference of Russian Young Researchers in Electrical and Electronic Engineering (EIConRus), Feb 2017, doi: 10.1109/EIConRus.2017.7910876

16. C. Kurupakorn; H. Kojima; N. Hayakawa; M. Goto; N. Kashima; S. Nagaya; M. Noe, "Recovery characteristics after current limitation of high temperature superconducting fault current limiting transformer (HTc-SFCLT)", IEEE Transactions on Applied Superconductivity, Volume: 15, Issue: 2, June 2005 doi: 10.1109/TASC.2005.849314

17. N. Hayakawa, S. Chigusa, N. Kashima, S. Nagaya and H. Okubo, "Feasibility study on superconducting fault current limiting transformer (SFCLT)", Cryogenics, vol. 40, pp. 325-331, 2000.

18. H. Kagawa, N. Hayakawa, N. Kashima, S. Nagaya and H. Okubo, "Experimental study on superconducting fault current limiting transformer for fault current suppression and system stability improvement", Physica C, vol. 372, pp. 1706-1710, 2002.

19. Naoki Hayakawa; Hiroki Kojima; Masahiro Hanai; Hitoshi Okubo, "Progress in Development of Superconducting Fault Current Limiting Transformer (SFCLT)", IEEE Transactions on Applied Superconductivity, Volume: 21, Issue: 3, June 2011doi: 10.1109/TASC.2010.2089412

20. C. Kurupakorn, H. Kojima, N. Hayakawa, M. Goto, N. Kashima, S. Nagaya, "Recovery characteristics after current limitation of High Temperature Superconducting Fault Current Limiting Transformer (HTc-SFCLT)", IEEE Trans. Applied Superconductivity, vol. 15, no. 2, pp. 1859-1862, 2005.

21. C. Kurupakorn, H. Kojima, N. Hayakawa, F. Endo, N. Kashima, S. Nagaya, "Simulation of electrical and thermal behavior of High Temperature Superconducting Fault Current Limiting Transformer (HTc-SFCLT)", Journal of Physics: Conference Series (JPCS), vol. 43, pp. 950-953, 2006.

22. K. Omura, H Kojima, N. Hayakawa, F. Endo, M. Noe and H. Okubo, "Current limiting characteristics of parallel-connected coated conductors for High-Tc Superconducting Fault Current Limiting Transformer (HTc-SFCLT)", IEEE Trans. Applied Superconductivity, vol. 19, no. 3, pp. 1880-1883, 2009.

23. M. Kotari, H. Kojima, N. Hayakawa, F. Endo and H. Okubo, "Development of 2 MVA class Superconducting Fault Current Limiting Transformer (SFCLT) with YBCO coated conductors", EUCAS2009, 2009.

24. H. Kojima, M. Kotari, T. Kito, N. Hayakawa, M. Hanai and H. Okubo, "Current limiting and recovery characteristics of 2 MVA class Superconducting Fault Current Limiting Transformer (SFCLT)", ASC2010, 2010.

25. W. R. Henning, A. D. Hernandez and W. W. Lien, "Fault Current Capability of Distribution Transformers with Under-Oil Arresters", IEEE PES Winter Meeting.

26. C. A. Popeck, W. A. Lewis and G. D. Allen, "The Application of Current Limiting to Distribution Circuit Protection", Electric Power Systems Research, vol. 1, pp. 67-86, 1977/78.

IoT Based Battery Monitoring and Protection System

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ABSTRACT

The global focus on sustainable energy solutions has propelled Electric Vehicles (EVs) into prominence as a crucial means to decrease carbon emissions and dependence on traditional fuels. However, maximizing EV performance, range, and overall sustainability hinges on effectively managing the vehicle's energy monitoring system, particularly the rechargeable battery. This paper explores the crucial role of an Internet of Things (IoT)-based battery monitoring system in optimizing EV usage and contributing to a more sustainable future. Through this system, real-time data on battery health, performance, and energy consumption can be gathered, analyzed, and utilized to enhance charging efficiency, extend battery life, and optimize overall EV operation. This research delves into the design, implementation, and advantages of an IoT-based battery monitoring system for EVs, paving the way for advancements in sustainable transportation and responsible resource utilization.

KEYWORDS: *Electric vehicle, Battery management system, Internet of Things, Battery health, Real-time data, Cloud computing.*

INTRODUCTION

Electric vehicles (EVs) are rapidly emerging as a key solution in the fight against climate change. By offering a clean alternative to gasoline-powered vehicles, EVs significantly reduce carbon emissions and our reliance on fossil fuels. However, unlocking the full potential of EVs depends on effectively managing their core power source: the battery. [1] optimizing the performance, range, and overall sustainability of EVs hinges on a robust and efficient battery management system (BMS). These complex batteries require careful monitoring to ensure optimal operation and lifespan.[2][6] While traditional BMS solutions exist, advancements in Internet of Things (IoT) technology offer a revolutionary approach.[3][5] This paper explores the critical role of IoT-based battery monitoring systems in enhancing EV efficiency and promoting a more sustainable future. We will examine the challenges associated with EV battery management and how real-time data acquisition through embedded sensors within the battery pack can be revolutionized by integrating IoT. [4][7]

By continuously collecting and transmitting critical battery data (voltage, cur- rent, temperature, etc.) to a central platform, this innovative approach unlocks a multitude of benefits, including:

a) Uninterrupted Data Monitoring: Constant access to vital battery health and performance data facilitates proactive maintenance and optimization strategies.

b) Remote Management: The ability to monitor and manage battery health and performance remotely enhances operational efficiency and user convenience.

c) Predictive Maintenance: Real-time data analysis allows for the identification of potential issues before they become critical failures, enabling preventative measures to be taken.

This research will delve into the design, implementation, and advantages of an IoT-based battery monitoring system for EVs. By harnessing the power of IoT technology, we aim to contribute significantly to the advancement of sustainable transportation and responsible resource utilization. This research focuses on developing, implementing, and evaluating a next-

generation IoT-based battery monitoring sys- tem for EVs with the following core functionalities. Real-time Battery Health Assessment: Continuously collect and transmit critical battery parameters like voltage, current, temperature, and state of charge (SOC) to enable uninterrupted monitoring of battery health and performance. Proactive Thermal management: Integrate features to detect and alert about temperature deviations exceeding safe operating ranges. This allows for prompt intervention and prevents potential thermal runaway scenarios. Short Circuit Mitigation: Implement functionalities to identify and isolate potential fault conditions within the battery pack, effectively reducing the risk of short circuits. Secure Cloud-based Data Storage and Access: Ensure collected data is securely stored on cloud servers, allowing authorized users to remotely access and analyses information with ease. Collaborative Battery Management: Facilitate the sharing of collected data with authorized personnel (e.g., vehicle owners, fleet operators, service providers) to enable collaborative monitoring, analysis, and decision-making regarding battery health and management across various stakeholder groups.

METHODOLOGY

This section outlines the development process for the next- generation IoT-based battery monitoring system.

System Design

Hardware Selection: We will select appropriate hardware components like microcontrollers, sensors (temperature, volt- age, current), communication modules (e.g., Wi-Fi), and optional components for enhanced functionality (cooling fan, fuses/relays, alarm system). Microcontroller Programming: The chosen microcontroller will be programmed to collect sensor data, perform real-time analysis, control actuators (e.g., cooling fan, alarm) based on thresholds, and communicate with the cloud platform.

Cloud Platform Selection: We will choose a secure and reliable cloud platform for data storage, visualization, and potential alert generation.

System Implementation

Hardware Assembly: The chosen hardware components will be assembled based on the finalized design specifications. Hardware-Software Integration: The hardware will be integrated with the software through programming and configuration to ensure seamless data flow. Cloud Platform Connection: Communication will be established between the system and the chosen cloud platform to enable data transmission and storage.

System Evaluation

Performance Testing: The system will undergo rigorous testing and evaluation to assess its performance in key areas: Data accuracy and reliability of sensor readings. Detection and alert functionality for potential battery issues. Actuator control effectiveness (e.g., cooling fan activation). Cloud plat- form integration efficiency for data transmission and storage. User-friendliness and accessibility of the system interface. Refinement Based on Findings: The results will be analyzed, and the system will be refined based on the identified areas for improvement.

Expected Outcomes

- Enhanced Safety: Early detection and intervention capabilities for potential battery issues will contribute to a safer operational environment for EVs.
- Improved Battery Reliability: Real-time monitoring and proactive management will help maintain optimal battery health and performance, leading to increased reliability and extended lifespan.
- Optimized Battery Efficiency: The system will provide valuable data insights to optimize charging strategies and maximize battery range.
- Sustainable Transportation Advancement: By promoting efficient and reliable battery management, the research contributes to a more sustainable future for electric transportation.

Significance of the Study

- This research offers valuable contributions to various stakeholders within the
- EV industry: EV Owners: Gain improved awareness of battery health and receive actionable insights for preventative maintenance and optimized charging practices.
- Fleet Operators: Enhance fleet management through

real- time monitoring and data-driven maintenance decisions, leading to cost savings and improved operational efficiency.

- Service Providers: Leverage real-time data on battery health and performance to improve diagnostic capabilities and service efficiency.
- Policymakers: Gain evidence-based knowledge to inform policy decisions and regulations promoting the adoption and safe operation of EVs. By addressing the limitations of existing battery monitoring systems and harnessing the potential of IoT technology, this research aims to advance EV battery management. This ultimately fosters a safer, more reliable, and sustainable future for electric transportation.

ESP32 Microcontroller

Industrial-Grade ESP32 PLC: This Programmable Logic Controller (PLC) leverages the ESP32 microcontroller, making it suitable for industrial environments. It offers a variety of communication options, including Wi-Fi, Bluetooth Low Energy (BLE), Ethernet/IP, and other industrial Ethernet protocols like Modbus TCP. Additionally, the ESP32 operates on low voltage levels, which can be beneficial for certain industrial applications. I/O Capabilities: The PLC boasts 48 general-purpose input/output (GPIO) pins, providing flexibility for connecting various industrial sensors and actuators. Key Points: Designed for industrial applications Supports Wi- Fi, Bluetooth LE,Ethernet/IP, and other industrial Ethernet protocols Low voltage operation 48 GPIO pins Applications of ESP32 Microcontrollers: ESP32's versatility makes it popular choice for various applications across different in- dustries. Here are some prominent examples: Smart Industrial Devices: Programmable Logic Controllers (PLCs) for indus- trial automation tasks. Industrial sensors and actuators for data collection and control. Smart Medical Devices: Wearable health monitors for tracking vital signs and fitness data. Medical equipment with wireless connectivity for remote monitoring. Smart Energy Devices: Heating, Ventilation, and Air Conditioning (HVAC) systems for efficient climate control. Smart thermostats for optimized energy usage. Smart Secu- rity Devices: Surveillance cameras with Wi-Fi or Bluetooth connectivity for remote monitoring. Smart locks with secure access control features. Understanding ESP32 Pin Function- ality: ESP32 microcontrollers come in various development board formats, each with its unique pin layout. It is crucial to understand pin functionalities to effectively utilize these boards in your projects. Why Pin Knowledge Matters Several factors necessitate familiarity with ESP32 pin layouts: Board Variation: ESP32 development boards come in diverse shapes and sizes, with differing pin configurations. Dedicated Pin Functions: Not all ESP32 microcontroller pins are accessible on a specific board. Some might be permanently assigned to dedicated functions like flash memory access. Maximizing Functionality: Understanding pin functionality allows you to choose the most suitable pins for your project's sensors, actuators, and communication protocols.

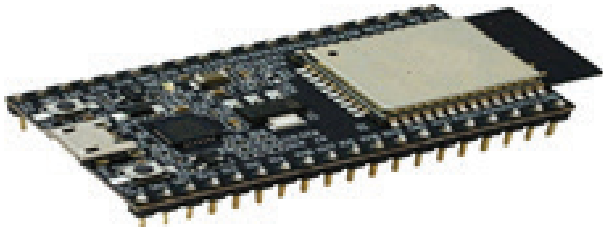

Fig. 1. ESP32

ESP32 Modules: Simplifying Development:

Express if Systems, the developers of the ESP32 microcontroller, created compact modules to ease integration into various development projects. These pre-built modules, like the popular ESP-WROOM-32, contain the core ESP32 chip along with essential components for functionality. Functional- ity Breakdown An ESP32 module typically incorporates the following elements:

ESP32 Microcontroller: The heart of the module, providing processing power and GPIO pins for interfacing with external components.

Flash Memory (SPI Flash IC): Stores program code for the microcontroller.

Crystal Oscillator: Maintains accurate timing for the micro- controller's operations.

PCB Antenna: Enables wireless communication capabilities (depending on the module variant).

Passive Components: Resistors, capacitors, and other elements to support circuit functionality.

Benefits of Using Modules:

ESP32 modules offer several advantages for developers:

Simplified Design: The pre-assembled module streamlines the development process by eliminating the need to design and source individual components, especially the complex RF (radio frequency) section.

Development Board Creation: Modules serve as the foundation for building custom development boards with additional features like user-friendly pin headers, USB ports, reset but- tons, and boot switches. Commercial Product Integration: Modules can be seam-lessly incorporated into final commercial products, reducing design complexity and development time.

Third-Party Innovation

Many manufacturers leverage ESP32 modules as building blocks for their development boards. These boards typically feature user-friendly breakout pins, USB ports, reset buttons, and boot switches, further enhancing ease of use for develop- ers.

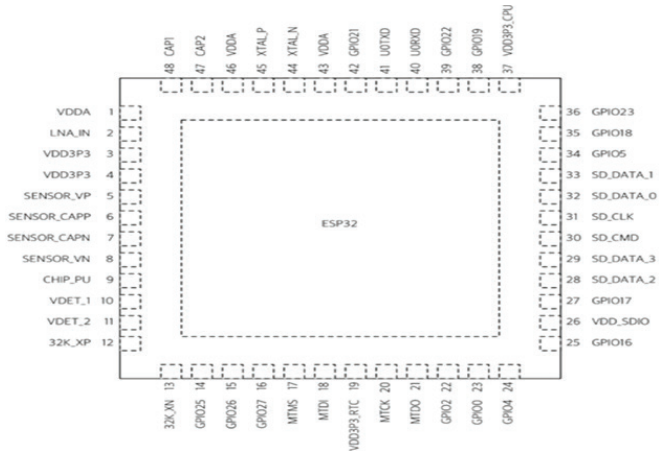

Fig. 2. ESP32 Pinout Structure

ESP32 Pin Considerations

Here are some key points to remember when working with ESP32 pins:

- SPI Flash Allocation: A portion of ESP32's general- purpose input/output (GPIO) pins might be dedicated to the on-board SPI flash memory, limiting their availability for other purposes. Input-Only Pins: Certain pins may be restricted to input functionality only. Interrupts: Some pins can trigger interrupts, allowing the microcontroller to react to specific events Bootstrapping Pins: Specific pins play a crucial role in the ESP32's boot process and should not be used for regular operations.

ESP32 Peripheral Overview

ESP32 microcontrollers boast a rich set of integrated peripherals, simplifying development for various applications. Let's explore some key functionalities:

General-Purpose Input/Output (GPIO): These versatile pins (34 in total) can be configured for various purposes like digital input, output, or communication protocols (UART, SPI, I2C) based on your project requirements. Analog-to-Digital Converter (ADC): ESP32 features two 12-bit ADC modules with a combined total of 18 channels. These channels convert analog signals from sensors (e.g., voltage, temperature) into digital values for processing. Digital-to-Analog Converter (DAC): Two independent 8-bit DAC channels convert digital data into analog voltage signals. This allows for controlling analog devices like actuators or audio signals. Pulse-Width Modulation (PWM): This functionality enables precise control over the power delivered to devices by rapidly switching a signal on and off. ESP32 offers 16 PWM channels for tasks like controlling motor speed or LED brightness.

Communication Interfaces: ESP32 provides various communication options: Universal Asynchronous Receiver-Transmitter (UART): En- ables serial communication with other devices like displays or sensors (3 interfaces).

Serial Peripheral Interface (SPI): High-speed communica- tion for peripherals like memory cards or displays (3 inter- faces).

Inter-Integrated Circuit (I2C): Low-speed communication for connecting multiple devices on a single bus (2 interfaces). Capacitive Touch Sensing: Ten GPIO pins have built-in capacitive touch sensing capability. This allows you to create touch-based interfaces without additional hardware.

Real-Time Clock (RTC) GPIOs: These 16 low-power GPIOs are part of the RTC subsystem and can be used to wake the ESP32 from deep sleep for specific events.

ESP32 Pin Usage Considerations

When working with ESP32 GPIO pins, it's crucial to consider several factors to ensure project success:

SPI Flash Allocation: Some ESP32 development boards, like the 30-pin version, might have certain GPIO pins (typ- ically GPIO6 to GPIO11) pre-allocated for the on-board SPI flash memory. These pins are not freely available for other purposes. Consulting the board's schematic is recommended. Input-Only Pins: A small subset of ESP32 pins (GPIO34, GPIO35, GPIO36, and GPIO39) are limited to input functionality only.

Bootstrapping Pins: Five specific ESP32 pins (GPIO0, GPIO2, GPIO5, GPIO12, and GPIO15) play a critical role in the boot process. Avoid using them for regular operations in your project.

I2C Communication

The ESP32 provides two I2C interfaces, enabling communication with various low-speed peripheral devices on a single bus. The default I2C pins for Arduino IDE are Serial Data (SDA): GPIO21 Serial Clock (SCL): GPIO22 PWM Functionality. The ESP32 boasts 16 independent PWM channels, offering precise control over power delivery to devices. Each channel allows configuration of frequency and duty cycle, making it suitable for tasks like controlling motor speed or LED brightness.

ESP32 as a Wi-Fi Station

In Wi-Fi station mode, the ESP32 acts as a client device, connecting to an existing Wi-Fi network (like your router). The router assigns a unique IP address to the ESP32, allowing communication with it from other devices on the same network.

Benefits of Station Mode

- Internet Access: Since the router is typically connected to the internet, the ESP32 in station mode can access online resources like weather APIs, publish data to cloud plat- forms, and utilize web elements like icons and JavaScript libraries.
- Communication with Other Devices: Devices connected to the same Wi-Fi network can communicate with the ESP32 using its IP address, enabling control and data exchange.

Alternative Mode: Access Point

While station mode is advantageous, situations might arise where a nearby network is unavailable, yet you require control of the ESP32. In such cases, configuring the ESP32 as an access point creates its own Wi-Fi network that other devices can connect to.

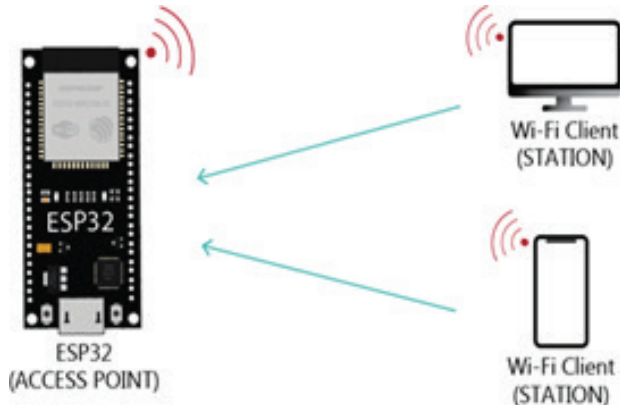

Fig. 3. IoT Interface

A popular choice for hobbyists and professionals alike,

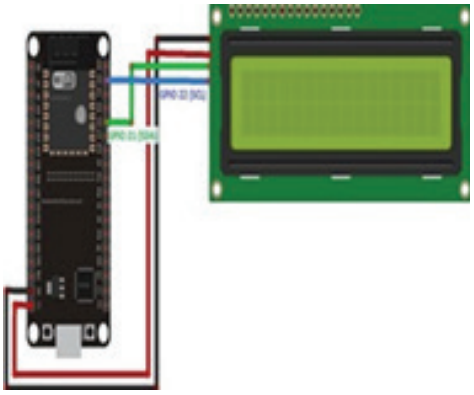

Fig. 4. 16x2 character LCD display

16x2 character LCD displays offer an affordable and user- friendly solution for text and character visualization.

Key Features

Display Capacity: 16 columns and 2 rows, totalling 32 characters.

Character Support: Alphanumeric characters, including let- ters, numbers, and symbols.

Custom Character Capability: Ability to define and display user-designed characters.

Operating Modes: 8-bit and 4-bit modes for data transmis- sion, with 4-bit mode being more common due to its reduced pin requirement.

Typical Specifications:

Operating Voltage: 4.7V to 5.3V

Operating Current: 1mA (without backlight) Pinout

Functionality:

Power Pins (Vss, Vcc): Vss connects to ground, while Vcc supplies power (typically 5V, but can operate within a range of 4.7V to 5.3V).

Control Pins: Contrast (VEE): Adjusts the character visibility on the display. Often connected to a potentiometer for user control.

Register Select (RS): Selects between the data register (for character data) and instruction register (for control commands) for the LCD.

Read/Write (R/W): In most cases, grounded as data is typically written to the LCD rather than read.

Enable (E): Triggers execution of a command sent to the LCD.

Data Pins (DB0 to DB7): Transmit data about the characters to be displayed. The display can operate in 4-bit mode (using DB4 to DB7) or 8-bit mode (using all eight pins).

Backlight Pins (LED+, LED-): Control the backlight illu- mination. LED+ typically connects to the power supply with a current-limiting resistor, while LED- connects to ground.

Relay Interface Circuit

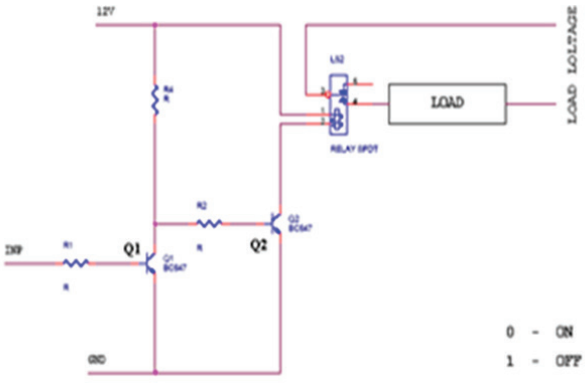

Fig. 5. hardware model

Circuit Components:

Transistors (Q1, Q2): These transistors act as electronic switches, amplifying the control signal to manage higher current loads. (BC547 is a common transistor type for this application, but the specific choice may vary depending on the load current.)

Relay: An electromagnetic switching device with three terminals:

Common (COM): Typically connected to the power supply voltage.

Normally Open (NO): Connects to the load in the on state. Normally Closed (NC): Optional connection, sometimes used for fail-safe mechanisms but not relevant in this circuit. Control Signal: A low voltage (often 0V) or high voltage (often 5V) signal that determines the relay state. Circuit

Operation:

Relay Off:

When a high control signal is applied to the base of Q1, it conducts. This shorts the collector and emitter of Q1, essentially bypassing it.

With Q1 conducting, the base of Q2 receives no voltage (or very low voltage), keeping it off.

Since Q2 is off, there is no current path between the common (COM) and normally open (NO) terminals of the relay. The load remains off.

Relay On:

When a low control signal is applied to the base of Q1, it turns off. This opens the path between the collector and emitter of Q1.

With Q1 off, the base of Q2 receives voltage (typically 12V in this example), turning it on.

The now-conducting Q2 creates a current path between the common (COM) and normally open (NO) terminals of the relay. The load receives power and turns on.

Relays: Electronic Control for Higher Currents

A relay is an electromechanical switch that uses a coil and electromagnetism to control a separate circuit. It essentially acts like a remote switch, where a low-power control signal governs a higher-power circuit.

How It Works:

Electromagnetic Actuation: The relay's core component is a coil. When current flows through the coil, it generates a magnetic field.

Magnetic Attraction: This magnetic field attracts a lever within the relay, causing it to move.

Switching Contacts: The lever is connected to contact points that function as a switch. These contacts can be in two states: Normally Open (NO): In the default state (no coil current), these contacts are open, interrupting the circuit.

Normally Closed (NC): (Optional) In some relays, these contacts are closed by default and open when the coil is energized.

Isolation and Amplification:

Circuit Separation: A key advantage of relays is the isolation between the control circuit and the switched circuit. The control circuit (often low voltage) remains completely separate from the high-power circuit being switched by the relay. This isolation enhances safety and prevents potential damage to sensitive control circuits.

Current Amplification: The control signal from electronic circuits (like microcontrollers) often carries a limited current. Transistors are frequently used in conjunction with relays to amplify this weak control signal. The transistor acts as an electronic switch, allowing the low-power control signal to trigger the higher current needed to activate the relay coil.

Applications:

Relays find application in various scenarios where a low- power control signal needs to manage a high-power circuit. Examples include:

AC Mains Switching: A low-voltage control circuit can activate a relay to switch high-voltage AC mains power.

Microcontroller Control of Devices: Microcontrollers with limited current output can use relays to control high-power devices like motors or lamps.

Logic Level Conversion: Relays can be used to interface between circuits with different voltage levels.

BLOCK DIAGRAM

This project outlines a system for monitoring and managing battery health using an ESP32 microcontroller. Here's a break- down of the key components and functionalities: Power Con- nection: Battery: Provides power for the system and potentially other devices.

Diode: Protects the circuit from current flowing in the wrong direction. The positive and negative terminals of the battery are connected through the diode before entering the main circuit.

Load Switching: DPDT Switch (Modified as SPDT): Contrary to the text, a Single Pole Double Throw (SPDT) switch is likely used here. It has three terminals center (common), normally open (NO), and normally closed (NC). In this setup, the battery is connected to the center terminal. Loading: When the switch is in the" loading" position, the load (e.g., 5 DC lamps) is connected to the normally open (NO) terminal, allowing current to flow to the lamps. Charging: The "charging" position is not implemented in this configuration with the SPDT switch.

Load Monitoring: ACS712 DC Current Sensor: Senses the current flowing through the load (lamps). The output voltage of the sensor is directly proportional to the current. Sub-circuit (Monitoring): The load is connected in series with a monitoring circuit that likely includes the current sensor.

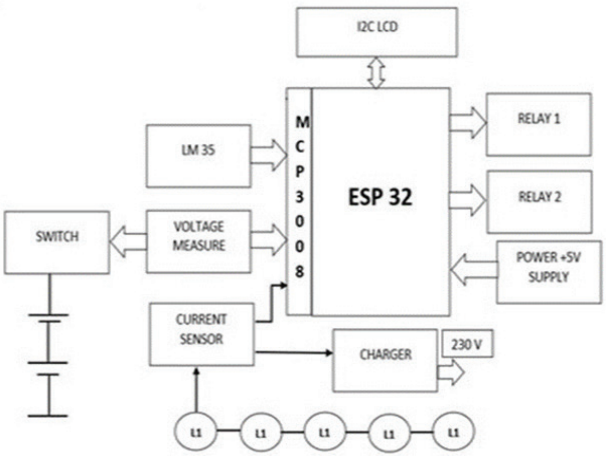

Fig. 6. Block diagram

Load Switching: DPDT Switch (Modified as SPDT) Contrary to the text, a Single Pole Double Throw (SPDT)

switch is likely used here. It has three terminals: center (common), normally open (NO), and normally closed (NC). In this setup, the battery is connected to the center terminal. Loading: When the switch is in the" loading" position, the load (e.g., 5 DC lamps) is connected to the normally open (NO) terminal, allowing current to flow to the lamps. Charging: The "charging" position is not implemented in this configuration with the SPDT switch. Load Monitoring: ACS712 DC Current Sensor: Senses the current flowing through the load (lamps). The output voltage of the sensor is directly proportional to the current. Sub-circuit (Monitoring): The load is connected in series with a monitoring circuit that likely includes the current sensor.

Voltage and Current Monitoring: Voltage Divider Circuit: Reduces the battery voltage to a level suitable for the ESP32 microcontroller's analog- to-digital converter (ADC). (The ESP32 and its ADC were mentioned in a previous section, but not explicitly here.) ADC (MCP3008, if applicable): An external ADC chip (MCP3008) might be used to convert the analog voltage signals from the current sensor and voltage divider circuit into digital values for the microcontroller to read. Overall, this system combines power management with load current monitoring. The configuration utilizes an SPDT switch for load control and an ACS712 sensor to track current consumption. The voltage divider and potentially an ADC convert analog signals into digital data for processing. Hardware Components: ESP32 Microcontroller: The central processing unit (CPU) of the system, responsible for collecting sensor data, controlling relays, and communicating with the cloud. It likely has built-in Wi-Fi and Bluetooth capabilities.

Battery: The power source for the system itself and potentially other devices.

Voltage Divider Circuit (with Reference to Datasheet): Re- duces the battery voltage to a level suitable for the ESP32's analog-to-digital converter (ADC). The specific resistor values should be determined based on the battery voltage and ADC input range (refer to the ESP32 datasheet for guidance).

Sugar Cube Relays: Compact relays used to switch circuits based on control signals from the ESP32. Their exact model (5017) might be a specific product reference.

Two Transistors per Relay: A transistor configuration likely used to amplify the control signal from the ESP32 to drive the relay coil effectively.

LCD Display: Provides a visual interface for displaying battery information like voltage, current, and temperature. It's connected to the ESP32's I2C communication pins (SDA and SCL) typically at pins 21 and 22.

LM35 Temperature Sensor: Senses the battery's temperature and sends the analog signal to the ESP32's ADC for conversion into digital values. Buzzer: Emits an audible alert when a critical battery condition is detected.

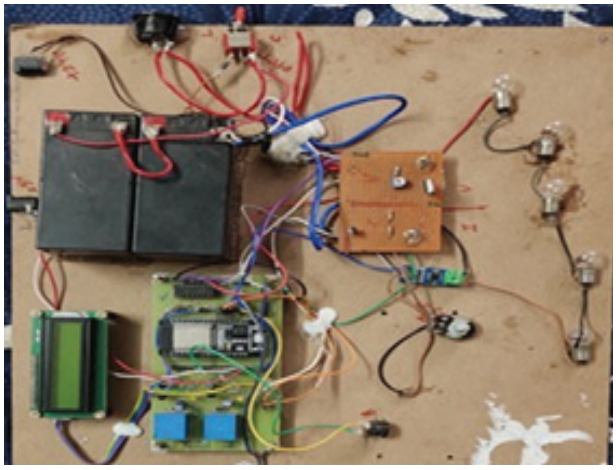

Fig. 7. Normal Working Condition

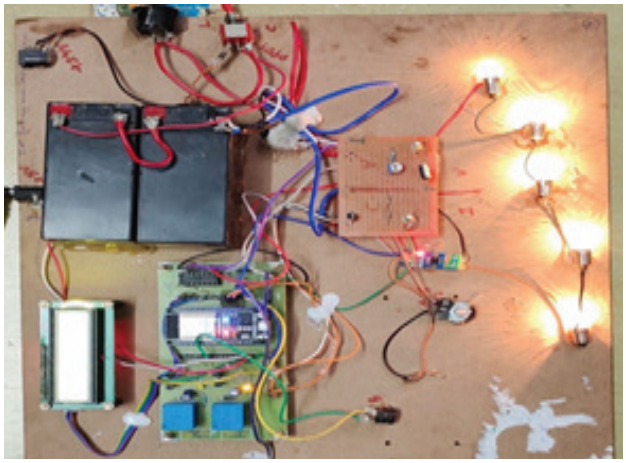

Fig. 8. Overload working Condition

Software Functionality: ESP32 Programming: The ESP32 is programmed to perform the following tasks:

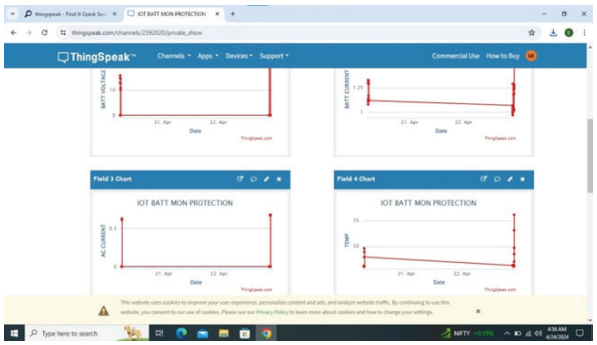

Fig. 9. IoT Interface

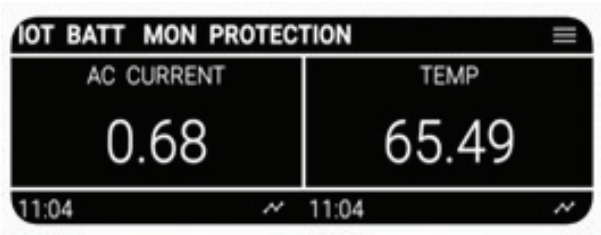

Fig. 10. Overheat Condition

OUTCOMES AND RESULT

1) Data Acquisition: Continuously reads voltage, current (likely using an external current sensor - not explicitly mentioned in the text), and temperature from the respec tive sensors.

2) Condition Checking: Compares the collected data against predefined thresholds for under-voltage, over- voltage, over-current, and over-temperature conditions.

3) Relay Control: Activates or deactivates the sugar cube relays based on the sensed conditions, potentially for actions like isolating the battery or taking corrective measures.

4) Buzzer Alert: Triggers the buzzer when a critical condi- tion arises, providing an immediate audio notification.

5) Cloud Communication: Transmits the collected battery data (voltage, current, temperature) to a cloud server using the ESP32's Wi-Fi or Bluetooth capabilities. Data Visualization: Cloud Server: Stores the historical battery data sent by the ESP32.

6) Web Interface: A web application accessible on a stan- dard web browser allows users to view the battery data remotely, potentially in graphical or tabular format, for monitoring trends and battery health.

Mobile App (Z07 Thym): A mobile application (potentially using the Z07 Thym framework) could be developed to provide a convenient way to access battery information from a smartphone or tablet. Overall, this project demonstrates a comprehensive battery management system using an ESP32 microcontroller. It offers features like data acquisition, condi- tion monitoring, relay control, buzzer alerts, and cloud-based data storage and visualization, making it a valuable tool for ensuring battery health and safety. Additional Considerations:

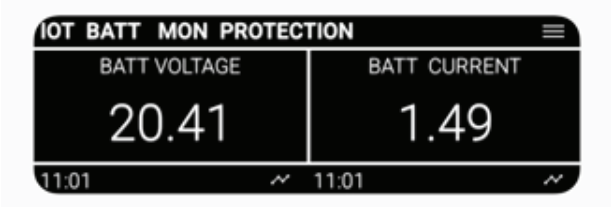

Fig. 11. Normal Voltage and Current Condition

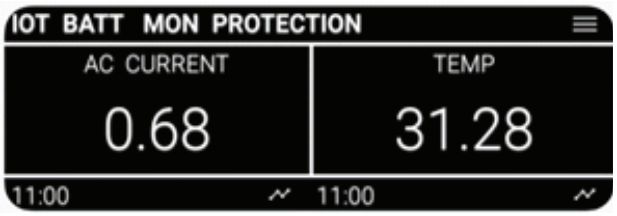

Fig. 12. Normal Temperature condition

While the text mentions a current value (7707A), it's highly unlikely to be accurate. Typical battery current ratings are in the range of milliamps (mA) or amperes (A). Double-check the current sensor specifications and scaling factors in your code.

The specific cloud server, web interface, and mobile app development would require additional details and programming expertise beyond the scope of the provided information.

CONCLUSION

The development of an IoT-based system aims to mitigate the risk of fire accidents in electric vehicle (EV) batteries by remotely monitoring battery health, the IoT-based battery monitoring system using ESP32 offers a

promising solution for efficient battery management. By using IoT technology, this system provides real-time monitoring and analysis, enhancing battery performance and durability. Its simplicity and effective- ness make it a valuable asset in various industries. Moving forward, continued research and development in this field will further optimize battery management systems, driving innovation and sustainability.

REFERENCES

1. Puma-Benavides, David Sebastian, et al. ”A systematic review of tech- nologies, control methods, and optimization for extended-range electric vehicles.” Applied Sciences 11.15 (2021): 7095.
2. Mathew, S. A., R. Prakash, and P. C. John. ”A shrewd remote battery observing framework for electric vehicles.” Int. Conf. Intel. Syst. Des. Appl. ISDA. 2012.
3. Menghua, Wang, and Xiao Bing. ”A real-time android-based monitoring system for the power Lithium-Ion battery used on EVs.” 2017 10th International Conference on Intelligent Computation Technology and Automation (ICICTA). IEEE, 2017.
4. Mathew, Shema Ann, Rb Prakash, and Philip C. John. ”A smart wireless battery monitoring system for Electric Vehicles.” 2012 12th International Conference on Intelligent Systems Design and Applications (ISDA). IEEE, 2012. Piao, Changhao, et al. ”VRLA battery management system based on LIN bus for electric vehicle.” Advanced Technology in Teaching: Selected papers from the 2012 International Conference on Teaching and Computational Science (ICTCS 2012). Springer Berlin Heidelberg, 2013.
5. Chatzakis, John, et al. ”Designing a new generalized battery manage- ment system.” IEEE transactions on Industrial Electronics 50.5 (2003): 990-999
6. Vekhande, Anjali, and Ashish Maske. ”Iot-Based Battery Parameter Monitoring System For Electric Vehicle.” International Journal Of Creative Research Thoughts (Ijcrt), ISSN (2020): 2320-2882.
7. Panicker, Dinesh, et al. ”IoT Based smart Battery Management System.” International Research Journal of Engineering and Technology (IRJET) 9.06 (2022).
8. Logeswaran, T., et al. ”IOT based full scale Battery Monitoring System.” International Journal for Scientific Research Development 7.2 (2019): 233-235.
9. Rukkumani, V., et al. ”IoT-based Battery Health Monitoring System for Electric Vehicle.” 2023 Second International Conference on Electronics and Renewable Systems (ICEARS). IEEE, 2023.

Study of Different Spectrum Detection Methods for Cognitive Radio Networks: A Review

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ABSTRACT

Cognitive radio spectrum Sensing is a potential technique that can effectively use the frequency spectrum that is accessible for future technologies and meet the requirement for high data transmission. For cognitive radio spectrum sensing to dynamically allocate unused spectrum to unlicensed users, licensed user signals must be detected. This study presents various research fields of bandwidth monitoring for cognitive radio networks and discusses a survey of the literature in the field.

KEYWORDS: *Spectrum, Cognitive radio, Licensed user.*

INTRODUCTION

Spectrum is becoming more and more necessary as wireless technologies advance quickly. Many studies have found that 25% to 75% of the allotted spectrum is free, meaning that it is being used inefficiently depending on the region [1]

The primary cause of spectrum scarcity is ineffective fixed spectrum distribution, indicating a decrease in the use of licensed spectrum. Finding open frequency bands is challenging due to the early distribution of the radio spectrum that is usable. Thus, the concept of offering new services is likewise met with resistance. In the event that the principal user (PU) is absent, the auxiliary user can use the licensed band without any disruption. This enhances the utilization of the Bandwidth.[2]

The issue of inefficient spectrum utilization in wireless communication is resolved by the application of cognitive radio. Cognitive radios use continuous spectrum sensing and channel identification to communicate over two or three decades of frequency. Cognitive radio can adjust its transmission parameters in response to changes in its surrounding [2]

Cognitive Radio Technology

With the use of cognitive radio, unlicensed users can efficiently exploit underutilized licensed spectrum through to wireless technologies.

The primary role of An smart wireless setup is detection of freely available bandwidth, which both detects accessible spectrum throughout the full spectrum to enhance user utilization and prevents detrimental interference with licensed users [3].

Within a clever wireless ecosystem, cooperative bandwidth detection enables secondary users (SU) to exchange information in order to decide whether the main user is there or not.

It is noted that the cognitive wireless is a novel strategy. This method is intended to determine that a specific wireless bandwidth segment is presently utilized or not, as well as to quickly enter the momentarily vacant bandwidth without interfering with other users' transmissions. [4]

Spectrum Sensing Techniques in Cognitive Radio

Spectrum sensing is a major challenge in CR. It defines to locate main users in a authorized bandwidth and quickly

depart the frequency range to prevent intervening with main user To determine whether the essential signal is there, several techniques are employed [5]

Fig 1: cognitive Radio sensing Example

Categorization of Spectrum Sensing Methodologies

The below diagram shows the classification of different spectrum sensing methodologies used in cognitive radio network for detection of idle bandwidth [7]

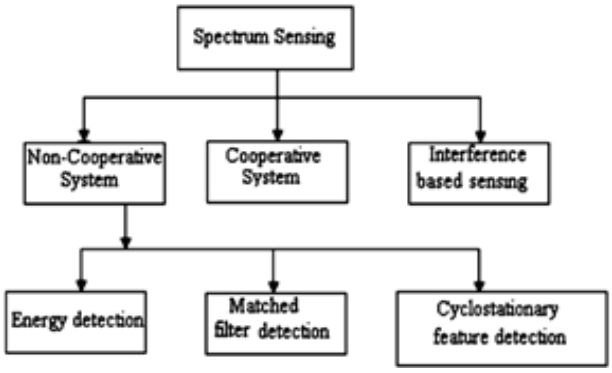

Fig. 2 : Spectrum detection classification

Non-cooperative Sensing technique

Here each CR determines whether primary signal is present or not within a particular spectrum. The figure above shows three variations of this, strategy.

Matched Filter Detection

Fig. 3: Matched filter detection

In the event that CR is aware of the primary signal beforehand, while using a coherent detector (matching filter) to detect. It is thought to be superior to other sensing methods. The signal-to-noise ratio (SNR) that is received is optimum. It is therefore extremely accurate

The matched filter finding process could be stated as

$$Y(n) = \sum h[n-k]X[k] \quad (1)$$

Where the unidentified signal is represented by X(k), the obtained frequency is denoted by y(n), and the matched filter's impulse response is represented by h[n-k].

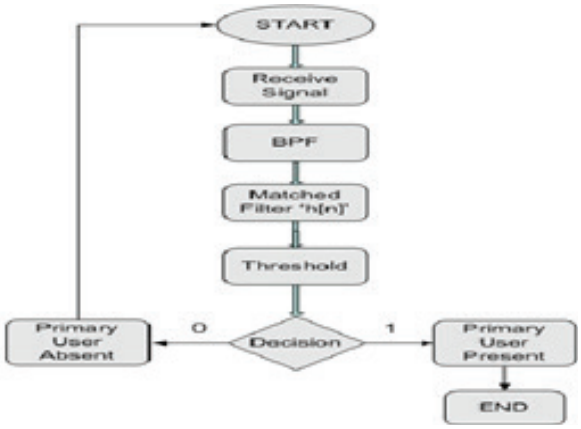

Fig. 4: Matched filter Process flow chart

The above figure 4 shows the flow chart of matched filter detection working mechanism

A band-pass filter is used to measure the energy in the area of the associated band before the input signal is transmitted through it. A match filter, whose impulse response is the same as the reference signal's, is used to convolve the BPF's output signal next. Finally, a threshold is compared to the matched filter out value to determine whether the principal user is present or not.

Energy Detection Method

One non-coherent detection technique is energy detection. An energy detector can be utilized in the event that the SU is unable to gather enough data regarding the PU signal. Another name for it is a radiometer. An energy detector needs to be aware of its noise power in order to be deemed a good option. It is a widely used technique for signal detection that is unknown.

There are three sections to the block diagram. They are an integrator, a squaring device, and a band pass

filter (BPF). The BPF chooses the precise frequency spectrum that the user wants to sense. Following the BPF's use for calculating the energy received, comes the squaring device. The observation interval is calculated by passing the squaring device's output through an integrator. A threshold value is used to compare the integrator output. The primary user is present if the values are higher than the threshold; otherwise, they are absent. Earlier information of the main client wave is not necessary.

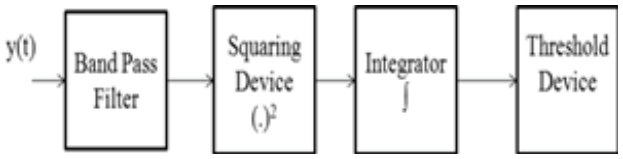

Fig. 5: Energy Detection

There is little computational or implementation complexity. Each of them is regarded as the advantages of an energy detector over alternative sensing techniques. The primary drawbacks are that satisfactory results require a lengthy sensing time. It is unable to distinguish between noise and the main user.

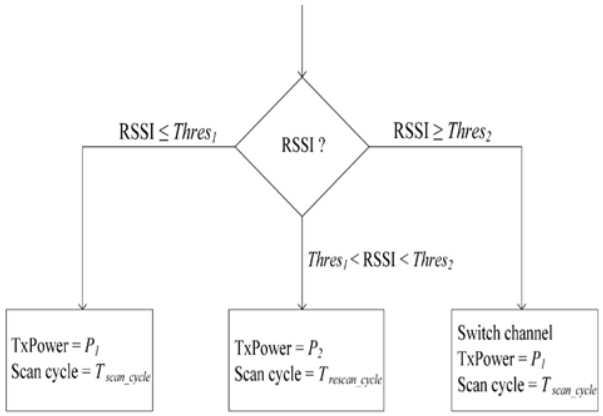

Fig. 6: Energy Detection Calculation flow chart

The above figure 6 shows the energy detection mechanism in Energy Detector based on Received Signal Strength Indicator (RSSI).

Based on whether the Received signal strength indicator (RSSI) is less then the threshold energy or more then the threshold energy it uses the different transmission powers and scan cycle time periods to detect the energy

Energy detector operates on the tenet that a choice is made at the end of reception after the power of the received signal is determined according to a threshold value.

When k = 1, 2,..., N at the signal detector is the part of the signal that was obtained and denoted by y(k), the choice metrics can be expressed as follows

$$E(K) = \begin{cases} H0 & \text{if } E < \lambda \\ H1 & \text{if } E > \lambda \end{cases} \quad (2)$$

Where

$E = E[|y(k)|^2]$ is the approximated power of the collected signal

λ= threshold value

H0= hypothesis of signal absence

H1= Hypothesis of signal Presence

Below Equation (3) shows the estimated power of the detected signal, which is provided by $\hat{E}$

$$\hat{E} = \frac{1}{N}\sum_{1}^{N} |y(k)|^2 \quad (3)$$

When N increases to a high number of samples, $\hat{E}$ settles to E. The amount of samples affects an energy spotter's performance

Cyclostationary Feature Detection

By achieving the timeline of the received main signal, primary users are detected. Typically, Spread spectrum sequences, sinusoidal carriers, and pulse trains all incorporate periodicity (Timeline). (Also known as hopping sequences and spread codes) of the main signal. [8]

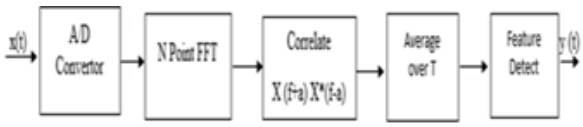

Fig. 7: Cyclostationary Feature Detection

The five sections of the block diagram are feature detection, correlate; average over T, band pass filters point FFT, and A/D converter. Noise uncertainties do not affect it. Under low SNR environments, it performs well. Understanding the signal's properties beforehand is necessary. Energy detection is more widespread in cooperative sensing; however this detection approach is less common due to its high computing complexity.

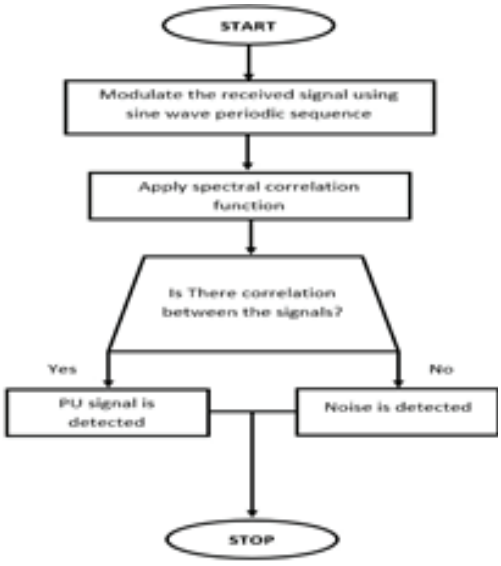

Fig. 8: Process flow chart of Cyclostationary Feature detection

The above fig 8 displays the process flow of Matched filter detection by using correlation between sensed signals.

Cooperative Spectrum Sensing

Collaborative spectrum detection lowers the likelihood of incorrect detection, false alarms, hidden node issues, and sensing times.

The following methods are included in the cooperative sensing category

Centralized Cooperative Sensing

Fusion Center, often known as Base Station, is the name of a central module in this. The cooperative spectrum sensing procedure is managed by it. Initially, a channel or frequency band is chosen for sensing by the fusion centre (FC). It provides specific sensing instructions to each collaborating CR. The findings of their sensing are reported by all collaborating CRs, second. The sensor data is finally combined by the fusion center. The PU's presence or absence is determined by it. The dispersed decision will then be sent back to the CRs.

Distributed Cooperative Sensing

Here, the CR users communicate with one another to arrive at a distinct choice regarding the existence or non-existence of PUs through repetitions [9].

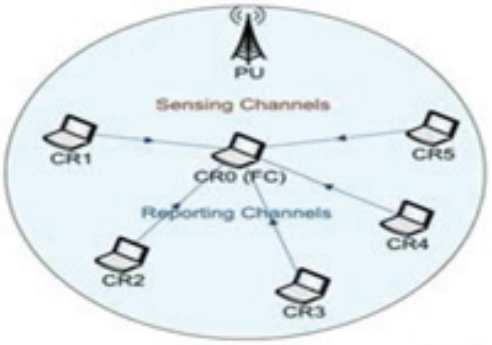

Fig. 9 : Centralized architecture

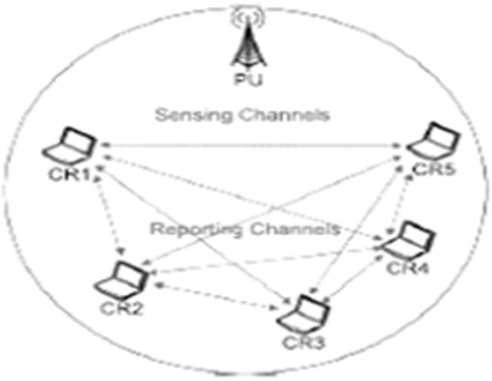

Fig. 10: Distributed Architecture

Relay assisted Cooperative Sensing

When the reporting pathway and sensing pathways aren't perfect, this kind of sensing is employed. The CR user notices that one CR user has a strong reporting medium and a poor sensing mechanism, whereas the other CR user has both [10]

Interference Based Spectrum Sensing

Primary receiver detection and interference temperature control is how it is categorized.

Primary Receiver Detection

The local oscillator leakage power is produced by the primary receiver's RF front end [9]. It happens after the primary transmitter sends the data. A cheap sensor node is positioned very near to the principal user's receiver in order to Identify PU. The band's occupancy state is calculated from the sensed data cycling through the CRs. By using this method, executing CR users on the surface of the spectrum allows for the discovery of spectrum possibilities [11]

Interference Temperature Management

For each frequency band, an upper interference limit is established in interference temperature management. Users cannot produce detrimental interference if they are utilizing a certain band in a designated location. By modifying the transmission power according to each transmitter's location [12] in relation to the primary users, interference from CR users is managed. Interference presented at the receiver is measured using this method. The temperature level at which interference occurs limits it. Thus, primary users are not adversely affected by it. Ultra Wide Band technology and its working concept are comparable.[13]

Comparison of different spectrum sensing techniques

Spectrum sensing method	Method Employed	Power Consumption	Primary detection in low SNR Conditions	Advantage
1) Matched Filter Detector	Uses filter to detect licensed user signal	High	Yes	Better Primary user detection in low SNR also
2) Energy Detector	Compares detected values with threshold values	Low	Yes	Ease of use & implementation
3) Cyclostationary Feature Detection	Uses feature of primary signals to detect their presence	Low	Yes	Strong & better Primary user detection than Energy detection
4) Cooperative spectrum sensing	Cooperation method is used among the secondary users for spectrum sensing	Low	Yes	Low false detection rate
5)Interference Based Spectrum Sensing	Uses a sensor node which is placed in close proximity to the main user	Low	Yes	Low disturbance to the main user

Spectrum Sensing Challenges

Hidden Licenced User Problem

Numerous elements, such as fading with multiple paths and job shadowing, contribute to masked node issues [22]. The concealed main consumer issue may be resolved by collaborative sensing.

Detecting Spread Spectrum Users

Commercial devices employ 2 different kinds of technologies: spread spectrum (FHSS and DSSS) and fixed frequency. It is tricky for PUs that employ spread spectrum messaging to identify PU energy that is scattered over a large frequency range. Absolute coordination can be accomplished and this difficulty somewhat avoided if the hopping pattern is understood [16].

Sensing Duration and Frequency

Detection technologies should be able to identify the main users during a specific time window to prevent interference with PUs. In order to ensure coordination among detecting time and accuracy of detection, it is crucial to select detection factors such as sensing frequency, pathway discovery time, and pathway move length.[18]

Security

An adversarial operator can modify its air interface to resemble the licensed user. It provides some false impressions concerning spectrum sensing. Principal User Emulation (PUE) attack is the term for this [22]. To prevent this kind of situation, digital modulations employ encryption with public keys algorithms.

CONCLUSION

Biggest challenge facing by today's modern wireless communication is. The efficient use of spectrum. It is simple to find unutilized licensed band bandwidth by using spectrum sensing techniques. Several spectrum sensing techniques are examined in this research by taking into account various white space perspectives. Novel possibilities and difficulties for spectrum sensing are brought about by the novel understanding of white space. Taking into account various spectrum sensing techniques, it may be inferred that individual sensing is unsuitable for precise primary user identification. Collaborative Bandwidth sensing is regarded as a potential remedy for prevalent issues in Bandwidth sensing under such circumstances. Future directions in this field of study will primarily focus on finding opportunities in several dimensions, including time, space, perspective, frequency, and encodes.

REFERENCES

1. Monika Yadav & Gaurav Verma, 'Minimizing the Probability of Error in Cognitive Radio Networks'- IEEE 12th International Conference on Computing Communication and Networking Technologies (ICCCNT)-2021
2. Clement Kam, Sastry Kompella , and Anthony Ephremides, 'Age of Sensed Information in a Cognitive Radio Network'-IEEE 19th International Symposium on Modeling and Optimization in Mobile, Ad hoc, and Wireless Networks (WiOpt)-ISBN 978-3-903176-37-9 © 2021
3. Raouia Masmoudi Ghodhbane, 'A Mixed Spectrum Sharing Strategy for Cognitive Radio Systems'-IEEE 2021 International Conference on Smart Applications, Communications and Networking-978-1-6654-3545-1/21/©2021 IEEE
4. Sihem Sehli, Malika Babes, 'A new efficient hybridization for spectrum allocation in cognitive radio networks'- 2020 IEEE International Symposium on Broadband Multimedia Systems and Broadcasting 978-1-7281-5784-9/20/©2020 IEEE
5. Morteza Alijani, Anas Osman, 'Performance Improvement of Energy Detection in Cognitive Radio Under Noise Uncertainty'-IEEE 2020 14th International Conference on Innovations in Information Technology (IIT)
6. M. Ashok, Rajesha. N, M. Ajay Kumar, 'Performance Analysis of Energy Spotting and Cyclostationary Methods in Cognitive Radio'-978-1-7281-1871-0/19©2019 IEEE
7. V Amrutha, K. V. Karthikeyan. "Spectrum sensing methodologies in cognitive radio networks: A survey" , 2017 International Conference on Innovations in Electrical, Electronics, Instrumentation and Media Technology (ICEEIMT), 2017
8. Khadeeja Sherbin.M, Ms. Sindhu. V, 'Cyclostationary Feature Detection for Spectrum Sensing in Cognitive Radio Network - Proceedings of the International Conference on Intelligent Computing and Control Systems (ICICCS 2019) IEEE Xplore Part Number: CFP19K34-ART; ISBN: 978-1-5386-8113
9. Karamahamdi,W Zhang, K. B. Latief, 'Power Control in Cognitive Radio Systems Based on Spectrum Sensing Side Information'- 2007 IEEE International Conference on Communications-1-4244-0353-7
10. Sattarhussain & Xavier N, 'Closed form analysis of relay based cognitive radio networks over Nakagami-m fading channels' IEEE Transaction on vehicular technology vol.63 no 3-2014
11. Nie. N & Cristina , ' Adaptive channel allocation spectrum etiquette for cognitive radio networks' –IEEE Proceedings on mobile network & applications-2005
12. Qiongwu, Junnizou & Kangingzhu, 'Power allocation in primary user assisted multi channel cognitive radio networks-IEEE scientific research on communication and networking-2013.
13. Bhawna Ahuja & Gurjitkaur, ' A novel two stage improved spectrum sensing for cognitive radio systems'-IEEE Conference on computing for sustainable development-2016
14) Avirup Das, Satish, Nabanita, 'Cooperative spectrum mobility in heterogeneous opportunistic networks using cognitive radio'-2015 IEEE 40th Conference on Local Computer Networks (LCN)
15. F. A. Khan, Ratnarajan, M. Sellathurai, 'Multiuser diversity analysis in spectrum sharing Cognitive Radio networks'-IEEE 2010 Proceedings of the Fifth International Conference On Cognitive Radio Oriented Wireless Networks and Communications
16. Munehiro Matsui; Kazunori Akabane; Hiroyuki Shiba, Kazuhiro Uehara, 'Prototype of a Cognitive Radio System with Cooperative Sensing and Interference

Alerting'-IEEE Prototype of a Cognitive Radio System with Cooperative Sensing and Interference Alerting

17. Vaclav Valenta; Zbynek Fedra; Roman Marsalek; Genevieve Baudoin; Martine Villegas, 'Towards Cognitive Radio networks: Spectrum utilization measurements in suburb environment'-IEEE Radio and Wireless Symposium-2009.

18. Jiang Zhu; Zhengguang Xu; Furong Wang; Benxiong Huang; Bo Zhang, 'Double Threshold Energy Detection of Cooperative Spectrum Sensing in Cognitive Radio'-IEEE 2008 3rd International Conference on Cognitive Radio Oriented Wireless Networks and Communications (Crown Com 2008)-2008

19. Ghaith Hattab; Mohamed Ibnkahla, 'Multiband Spectrum Access: Great Promises for Future Cognitive Radio Networks'-IEEE Proceedings-2014.

20. Mikio Hasegawa; Hiroshi Hirai; Kiyohito Nagano; Hiroshi Harada; Kazuyuki Aihara, 'Optimization for Centralized & Decentralized Cognitive Radio Networks'- IEEE Proceedings-2014

21. Ashish Muralidharan, Prajwa L Venkateshwaran, S. G. Ajay, D. Arun Prakash, Mohandeep, 'An adaptive threshold method for energy based spectrum sensing in Cognitive Radio Networks' -IEEE 2015 International Conference on Control, Instrumentation, Communication and Computational Technologies (ICCICCT)-2015vol.60, no. 2, pp. 681 –690, feb.2015

22. T. Yucek and H. Arslan, "A survey of spectrum sensing algorithms for cognitive radio applications" , IEEE Communications Surveys Tutorials., vol. 11, no. 1, pp. 116-130, 2009.

Robust Classification of Voltage Sag Causes via Hilbert Transform and Soft Computing

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ABSTRACT

This research paper presents a novel methodology for classifying the underlying causes of voltage sag using the Hilbert Transform in conjunction with soft computing techniques. Voltage sags, characterized by short-duration drops in voltage levels, can significantly impact the reliability and performance of electrical power systems. Accurate identification of their causes is essential for implementing effective mitigation strategies. In this study, the Hilbert Transform(HT) is employed to extract distinctive features from voltage and current waveform during sag events. These features are then analyzed using soft computing techniques such as K-Nearest Neighbor (KNN), to classify the causative factors. The proposed approach is validated through extensive simulations data, demonstrating its efficacy and robustness in accurately diagnosing voltage sag causes. The findings suggest that this integrated method can significantly enhance the reliability of power systems by enabling more precise and timely interventions.

KEYWORDS: *Root causes of voltage sags, Hilbert Transform (HT), K-Nearest Neighbour (KNN).*

INTRODUCTION

Voltage sags are transient reductions in voltage levels that can last from a few milliseconds to several seconds, often causing significant disruptions in power quality and reliability in electrical power systems. These disturbances can result from various factors such as faults, abrupt load changes, and transformer energizing. Understanding the underlying causes of voltage sags is crucial for developing effective mitigation strategies and ensuring the stability of power systems.

Recent advancements in power quality disturbance detection have focused on hybrid methodologies that combine signal processing techniques like the Stockwell Transform and Hilbert Transform for enhanced accuracy in time-frequency localization, particularly in complex scenarios[1]-[3].The integration of machine learning algorithms, such as SVMs and decision trees, has further improved the robustness of disturbance classification, even in noisy environments [6]-[11]. Additionally, studies have adapted these techniques for use in renewable energy systems, addressing the challenges posed by the variability of these sources[7]-[18]. Comprehensive reviews underscore the trend toward AI-based and hybrid methods, which are increasingly seen as essential for reliable power quality monitoring in modern, renewable-rich grids [19]-[28].

In recent years, substantial research has been conducted to identify and classify the sources of voltage sags. Traditional methods, primarily based on waveform analysis and statistical approaches, have provided valuable insights but often fall short in terms of accuracy and adaptability to diverse conditions. The Hilbert Transform has emerged as a powerful tool for signal processing in power systems, offering a means

to analyze and extract features from voltage waveforms that can reveal underlying sag causes. Its ability to provide instantaneous amplitude and phase information makes it particularly suitable for characterizing voltage disturbances.

Soft computing techniques, including neural networks, support vector machines, KNN etc. have shown promise in handling the complexity and variability inherent in power system disturbances. Neural networks, with their capacity for learning and pattern recognition, can adapt to various types of voltage sags by training on historical data. Support vector machines, which excel in classification tasks, can effectively distinguish between different sag causes based on extracted features.KNN is particularly useful in power quality disturbance classification due to its ability to handle complex, non-linear relationships without making any assumptions about the data distribution. Its simplicity, ease of implementation, and robustness to noise make it a valuable tool for distinguishing between various types of disturbances such as sags.

Several studies have explored the application of these techniques individually and in combination. For instance, neural networks have been used to predict voltage sag events by learning from past occurrences. Support vector machines have demonstrated high accuracy in distinguishing between sag causes, particularly when used with feature extraction methods like the Wavelet Transform.KNN's simplicity, non-parametric nature, and effectiveness in handling multi-dimensional data make it a suitable choice for voltage sag cause analysis. It can leverage historical data to identify patterns and provide reliable classification, aiding in the efficient management and mitigation of voltage sag events.

Despite these advancements, there remains a need for an integrated approach that leverages the strengths of both the Hilbert Transform and soft computing techniques to improve classification accuracy. This paper aims to address this gap by proposing a comprehensive methodology that combines the feature extraction capabilities of the Hilbert Transform with the adaptive and robust classification power of neural networks, support vector machines and KNN.

The proposed methodology is validated through extensive simulations and analysis of real-world data, highlighting its potential to enhance the precision and reliability of voltage sag classification. By accurately identifying the underlying causes of voltage sags, this approach can contribute to more effective mitigation strategies, ultimately improving the resilience and stability of electrical power systems.

HILBERT TRANSFORM

The Hilbert Transform is a mathematical tool used to derive the analytic representation of a real-valued signal. By providing a way to shift the phase of each frequency component by 90 degrees, it transforms a real-valued signal into a complex-valued signal, facilitating various signal processing tasks. Mathematically, for a given real-valued time-domain signal , the Hilbert Transform is defined as:

$$\hat{x}(t) = \frac{1}{\pi} P.V. \int_{-\infty}^{\infty} \frac{x(\tau)}{t-\tau} d\tau \quad (1)$$

where P.V. denotes the Cauchy principal value of the integral. The Hilbert Transform shifts each frequency component of the signal by 90 degrees, effectively generating a quadrature signal. The analytic signal is then formed as:

$$z(t) = x(t) + j\hat{x}(t) \quad (2)$$

where j is the imaginary unit. This analytic signal has the original signal as its real part and the Hilbert Transform as its imaginary part.

The Hilbert Transform is particularly useful in applications such as envelope detection, modulation, and demodulation in communications, and instantaneous frequency analysis. By providing both amplitude and phase information, it allows for a comprehensive analysis of signals, making it an invaluable tool in various fields of signal processing.

K-NEAREST NEIGHBOR (KNN)

K-Nearest Neighbors (KNN) is a non-parametric algorithm used for classification and regression. It classifies a data point based on the majority class of its K- nearest neighbors, determined by a distance metric like Euclidean distance.

Euclidean Distance: For points $x = (x_1, x_2, \ldots\ldots x_n)$ and $y = (y_1, y_2, \ldots\ldots y_n)$:

$$d(x,y) = \sqrt{\sum_{i=1}^{n}(x_i - y_i)^2} \quad (3)$$

Steps of Algorithm:

1. Training Phase: Store all training data points and their labels.
2. Prediction Phase:

For a test point :

i. Calculate distances to all training points.

ii. Identify the nearest neighbors.

3. Classification: Assign the class based on the majority class:

$$\hat{c} = mode\ (c_{(1)}, c_{(2)}, \ldots, c_{(K)}) \quad (4)$$

4. Regression: Predict the value y^ hat{y}y^ by averaging the values of the nearest neighbors:

$$\hat{y} = \frac{1}{K}\sum_{j=1}^{K} y(j) \quad (5)$$

KNN is simple and versatile but computationally intensive and sensitive to the choice of KNN and the distance metric.

METHODOLOGY FOR VOLTAGE SAG UNDERLYING CAUSE IDENTIFICATION

The proposed methodology involves multiple stages, beginning with signal generation and ending with the identification of the underlying cause of voltage sag. Below is a detailed step-by-step explanation:

Signal Generation Stage

In the first stage, voltage sags are generated under various scenarios representing different underlying causes. These scenarios may include normal operations, induction motor (IM) starting, transformer energization, and LLLG fault. The voltage sags due to different underlying cause simulation are carried out in the matlab [14]. The voltage and current data are sampled at a sampling frequency of 10 kHz as shown in fig.1 & 2. The key objective here is to capture the voltage and current signals that exhibit characteristics related to the specific causes of voltage sags.

Signal Processing I Stage

The voltage and current signals obtained from the previous stage are processed using the Hilbert Transform (HT). The HT is a powerful tool in signal processing that helps in extracting the instantaneous amplitude, frequency, and phase of a signal. By applying the HT to the voltage and current signals, it becomes possible to highlight certain features that are indicative of different underlying causes of voltage sags. The processed signals are then used to create a Hilbert plot.

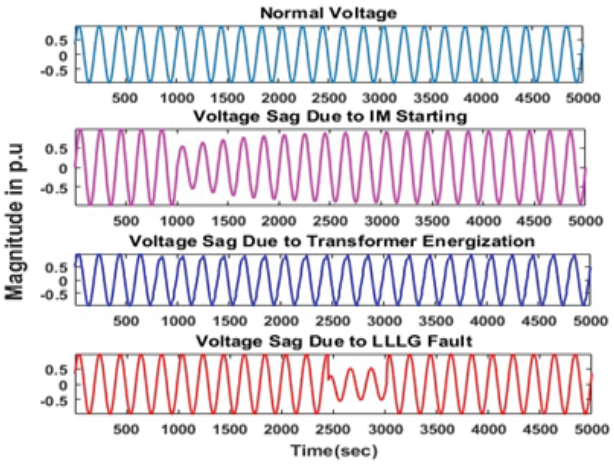

Fig. 1 Healthy Voltage and Voltage Sag Waveforms of Different Root Cause

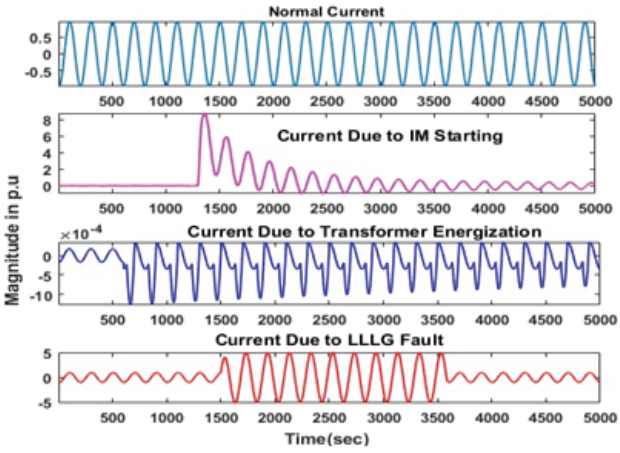

Fig. 2. Healthy Current and Current Waveforms Due to Different Root Cause

Signal Processing II Stage

In this stage, the Hilbert plot generated from the processed signals is converted into a visual format and saved as an RGB image. This visual representation allows for better analysis of the signal characteristics by transforming the time-domain information into a spatial format. The RGB image preserves the details of the signal in a format that can be further processed for feature extraction.

Image Processing Stage

The RGB image obtained in the previous stage is converted into a grayscale image. This conversion simplifies the image by reducing it to a single intensity channel, thereby removing color information that may not be essential for feature extraction. The grayscale image retains the structural details necessary for the subsequent stages of analysis.

Feature Extraction Stage

In this stage, statistical parameters are calculated from the grayscale image. These parameters may include features such as mean intensity, standard deviation, skewness, kurtosis, and other texture-related metrics. The goal is to extract meaningful features that capture the underlying patterns in the voltage sag signals, which can be used to differentiate between the different causes of voltage sag. The statistical features extracted from the gray scaled image of HT of both voltage and current signals like Mean, Standard Deviation, Entropy, Skewness, Kurtosis, Energy and Homogeneity

Classification Stage

Once the features are extracted, they are compiled into a feature vector that serves as input for a classification algorithm. The classifier is trained using labeled data, where each label corresponds to a known cause of voltage sag. During the testing phase, the classifier is used to predict the underlying cause of voltage sag based on the extracted features from new, unlabeled data. In this paper KNN is used as a classifier.

Decision Stage

Finally, the decision stage involves interpreting the output of the classifier to identify the specific cause of the voltage sag. The classification result is compared against predefined categories, such as normal operation, IM starting sag, transformer energization sag, and LLLG fault . The identified root cause is then used for further analysis or for taking corrective actions in the power system. The flow chart of the proposed methodology as shown in fig. 3.

RESULT AND DISCUSSION

The figure 4 shows Hilbert plots of voltage sag waveforms due to different underlying causes. Each plot is a result of applying the Hilbert Transform (HT), which provides a way to analyze the signal's instantaneous amplitude and phase by mapping the real axis (representing the original signal) against the imaginary axis (representing the Hilbert-transformed signal).

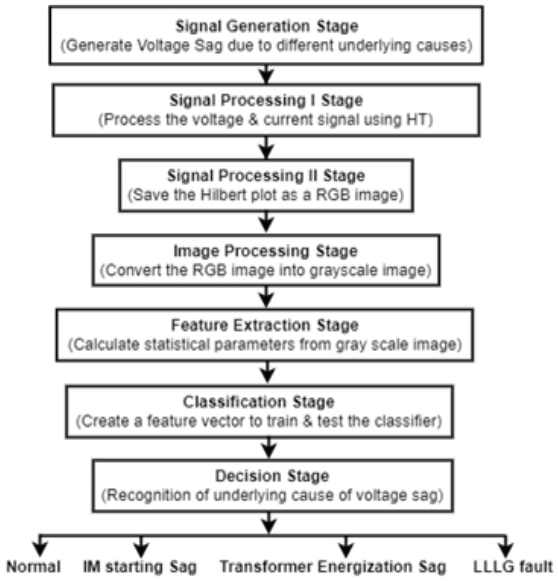

Fig. 3. Flowchart of Proposed Methodology

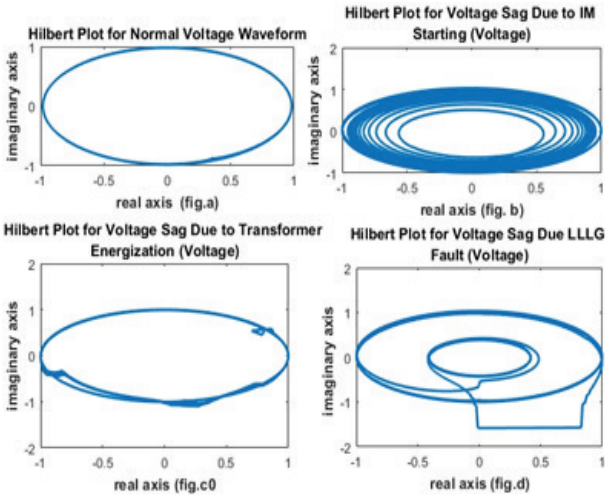

Fig. 4. Hilbert Plot A. Normal Voltage B. Voltage Sag Due to IMS C. Voltage Sag Due to TE D. Voltage Sag Due to LLLG Fault

Hilbert Plot for Normal Voltage Waveform (Fig. 4A)

This plot showcases the Hilbert representation of a normal, undisturbed voltage waveform. The plot appears as a near-perfect ellipse, indicating a steady and

consistent sinusoidal waveform without any significant perturbations or distortions. The uniformity of the ellipse reflects the stability of the voltage signal under normal operating conditions.

Hilbert Plot for Voltage Sag Due to IM (Induction Motor) Starting (fig. 4B):

In this plot, the effects of an induction motor starting are evident. The Hilbert plot shows a more complex pattern with multiple concentric ellipses, signifying the presence of a voltage sag. This disturbance occurs as the induction motor demands a high inrush current during startup, leading to a temporary reduction in voltage magnitude, which is captured by the Hilbert transform as changes in the signal's amplitude and phase.

Hilbert Plot for Voltage Sag Due to Transformer Energization (fig. 4C)

This plot depicts the voltage sag caused by the energization of a transformer. The pattern is slightly distorted compared to the normal voltage waveform, reflecting the transient nature of the sag. The irregularities and deviations from the elliptical shape indicate the disturbances in the voltage signal as the transformer are energized, causing a momentary drop in voltage.

Hilbert Plot for Voltage Sag Due to LLLG Fault (fig. 4D)

This plot represents a severe voltage disturbance caused by a Line-Line-Line-Ground (LLLG) fault. The Hilbert plot exhibits significant deviations from the elliptical shape, with multiple loops and irregular patterns. This complexity indicates a major disruption in the voltage waveform, characterized by a deep and prolonged sag, which is typical of a severe fault involving multiple phases and ground.

These Hilbert plots effectively illustrate how different disturbances affect the voltage waveform, providing a visual means to differentiate between normal conditions and various types of sags. The variations in the plots' shapes and complexity underscore the utility of the Hilbert Transform in identifying and analyzing power quality disturbances in electrical systems. Similarly, the hilbert plots of current waveforms due to different underlying causes are shown in figure 5.

Comparison Between Voltage and Current Hilbert Transform (HT) Plots

The Hilbert Transform plot (fig4.A) for voltage and current waveforms (fig5.A) provide distinct visual patterns that can help in recognizing the underlying causes of voltage sags. Both normal voltage and current HT plots are nearly identical under normal conditions, as no significant disturbances are present.

The Hilbert plot (fig4.B) for voltage during IM starting shows multiple concentric loops, reflecting the impact of the inrush current on the voltage waveform. The current plot (fig 5.B) also displays a series of concentric loops, but with a more pronounced and complex structure, indicating the high magnitude of inrush current. The current plot exhibits more complexity and a larger spread compared to the voltage plot, which signifies that the current waveform is more heavily disturbed during motor starting.

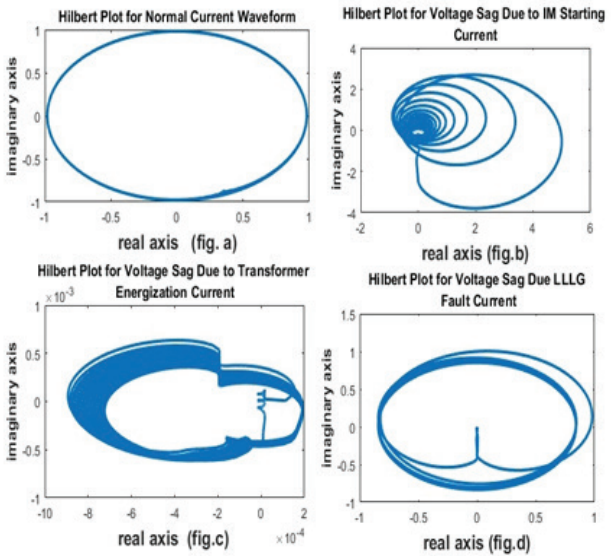

Fig. 5. Hilbert Plot of A. Normal Current B. Current Due to IMS C. Current Due to Te D. Current Due to LLLG Fault

The voltage Hilbert plot (fig4.C) shows a distorted shape, indicating a transient event with significant deviations from the normal sinusoidal waveform. The current plot(fig5.C) is highly irregular and significantly deviates from the normal elliptical shape, showcasing the substantial inrush current during transformer energization. The current plot is more irregular and

complex than the voltage plot, making it easier to identify transformer energization by observing the sharp deviations in the current waveform.

The Hilbert plot (fig4.C) for voltage during an LLLG fault is highly irregular, with multiple loops and deviations indicating a severe disruption. The current plot (fig5.D) also displays an irregular and complex pattern, with even more pronounced deviations compared to the voltage plot. Both plots show significant irregularities, but the current plot often exhibits sharper and more chaotic patterns, which helps in distinguishing the severity and nature of the fault.

Key Differentiations for Recognizing Underlying Causes

Current plots generally exhibit greater deviations in magnitude and complexity in their patterns compared to voltage plots, especially during events like motor starting and transformer energization. The pattern complexity of the Hilbert plot (e.g., number of loops, spread, and irregularity) is typically higher in current waveforms, which can be a key indicator in identifying the type of disturbance. Severe disturbances like LLLG faults cause significant irregularities in both voltage and current plots, but the current plot tends to show more pronounced deviations, making it more effective in diagnosing severe faults. By analyzing these differences, one can more accurately recognize the underlying causes of voltage sags, with current waveforms often providing clearer indications of the disturbance's nature and severity.

K-Nearest Neighbor (KNN) Result

To classify the underlying reasons of voltage sags KNN classifier is used. The image processing approach is used. The HT images are used for the training. During this period the statistical parameters are computed. The image used for the test purpose same statistical parameters are computed then distances are calculated for the class recognition. The figure 6 represents a test result of Hilbert plot for a "Normal Current" waveform with a pop-up message indicating "Detected Class=1." This likely indicates the result of a classification model, such as a K-Nearest Neighbour (KNN) classifier, that has identified the waveform as belonging to Class 1, which corresponds to a normal current condition. The plot shows a nearly perfect elliptical shape, which is typical for a normal current waveform. This shape suggests that the signal is undisturbed and is operating under normal conditions. The pop-up message with "Detected Class=1" confirms that the classifier has correctly identified this waveform as belonging to the class associated with normal operating conditions. The elliptical shape of the Hilbert plot aligns with expectations for a normal current waveform, confirming the absence of disturbances or anomalies in the signal. The classification system's detection of "Class=1" indicates that the waveform has been accurately recognized as normal by the KNN classifier. This result supports the effectiveness of the classification model in distinguishing between normal and abnormal conditions. This result serves as a validation step, ensuring that the classification model correctly identifies normal conditions, which is crucial for accurately detecting and diagnosing voltage sags and other disturbances.

The figure 7 represents a test result of Hilbert plot for a "Current Due to IM Starting" waveform with a pop-up message indicating "Detected Class=2." This likely indicates the result of a classification model, such as a K-Nearest Neighbours (KNN) classifier, that has identified the waveform as belonging to Class 2, which corresponds to a specific condition during the starting phase of the induction motor.

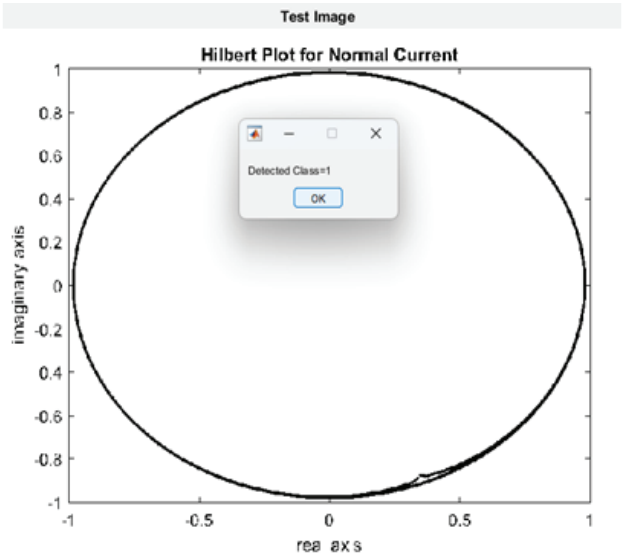

Fig. 6. Hilbert Plot for Normal Current Waveform with KNN Classification Result (Class=1)

The plot displays a spiralling pattern that gradually expands outward, which is typical for current waveforms during the starting phase of an induction motor. This spiral shape suggests that the signal is undergoing a transient state as the motor starts, which is expected behaviour. The pop-up message with "Detected Class=2" confirms that the classifier has identified this waveform as belonging to the class associated with the starting condition of the induction motor. The spiralling shape of the Hilbert plot is consistent with what is expected during the motor's startup phase. This shape indicates that the current is in a dynamic state, transitioning from an idle or off state to full operation as the motor begins to run. The classification system's detection of "Class=2" indicates that the waveform has been accurately recognized as corresponding to the motor starting condition by the KNN classifier. This result supports the effectiveness of the classification model in distinguishing between different operational states of the motor. This result is crucial for ensuring that the classification model can correctly identify various conditions, such as motor startup, which is essential for monitoring and diagnosing the performance of induction motors.

The figure 8 represents a test result of Hilbert plot for a "Current Due to Transformer Energization" waveform, with a pop-up message indicating "Detected Class=3." This suggests that the classification model, such as a K-Nearest Neighbors (KNN) classifier, has identified the waveform as belonging to Class 3, which corresponds to the condition during transformer energization. The plot shows a distinctive shape that initially expands rapidly and then gradually stabilizes. This pattern is characteristic of the inrush current that occurs during transformer energization, reflecting the transient and dynamic behavior of the current as the transformer is energized. The pop-up message with "Detected Class=3" confirms that the classifier has correctly identified this waveform as belonging to the class associated with the transformer energization condition. The unique shape of the Hilbert plot corresponds to the inrush current typically observed during transformer energization. This shape indicates a significant transient event, which is normal during the energization process but differs from the steady-state conditions seen in normal operation. The classification system's detection of "Class=3" indicates that the waveform has been accurately recognized as corresponding to the transformer energization condition by the KNN classifier. This result supports the effectiveness of the classification model in identifying specific electrical events, such as transformer energization. This result is crucial for ensuring that the classification model can correctly identify different operational conditions, such as transformer energization, which is essential for monitoring and protecting electrical equipment during such transient events.

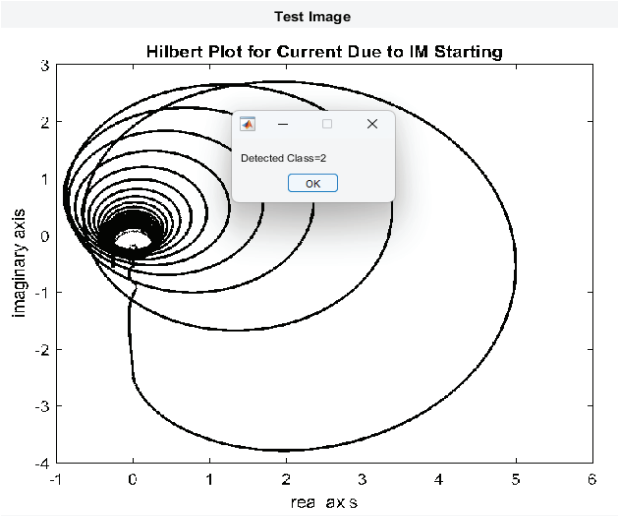

Fig. 7. Hilbert Plot for IMS Current Waveform with KNN Classification Result (Class=2)

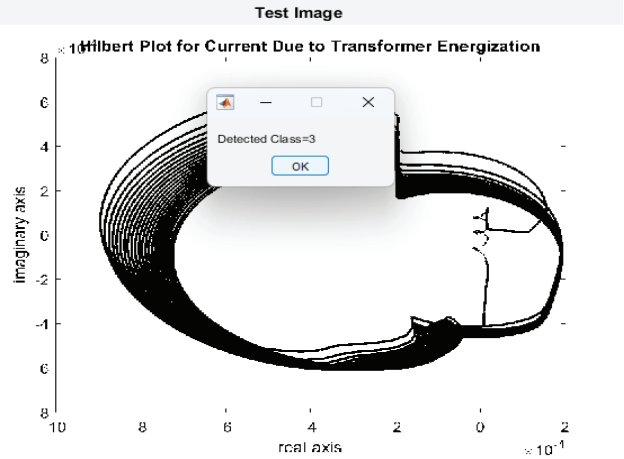

Fig. 8. Hilbert Plot for Current of TE with KNN Classification Result (Class=3)

The figure 9 represents a test result of Hilbert plot for a "Current Due to LLLG Fault" waveform, with a pop-up

message indicating "Detected Class=4." This suggests that the classification model, such as a K-Nearest Neighbors (KNN) classifier, has identified the waveform as belonging to Class 4, which corresponds to a condition involving a three-phase-to-ground fault (LLLG fault). The plot displays a distinctive shape that forms a loop with a pronounced bulge, which is typical for current waveforms during a severe fault condition like an LLLG fault. This shape reflects the highly disturbed and unbalanced nature of the current during such a fault. The pop-up message with "Detected Class=4" confirms that the classifier has correctly identified this waveform as belonging to the class associated with an LLLG fault condition. The unique looped shape of the Hilbert plot is consistent with what is expected during a severe fault condition like an LLLG fault. This pattern indicates significant disturbances in the current, characterized by high levels of asymmetry and unbalance, which are typical of this type of fault. The classification system's detection of "Class=4" indicates that the waveform has been accurately recognized as corresponding to an LLLG fault condition by the KNN classifier. This result validates the effectiveness of the classification model in identifying critical fault conditions, which is essential for the protection and safety of electrical systems

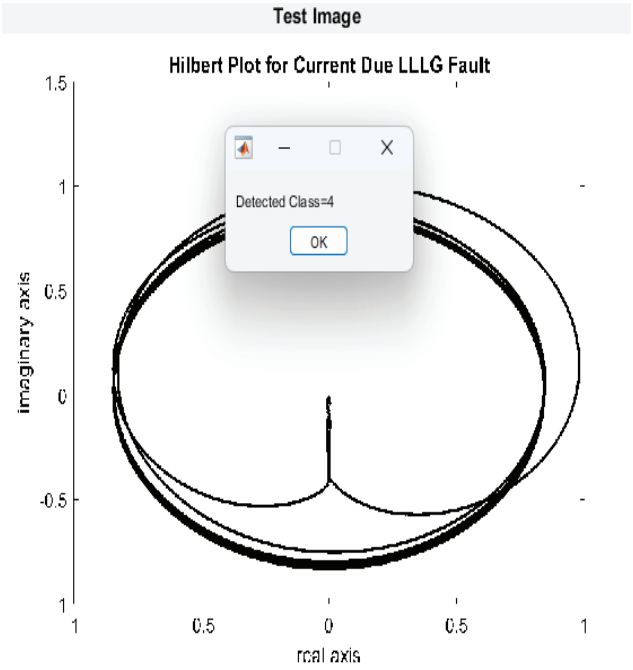

Fig. 9. Hilbert Plot for Current of LLLG Fault with KNN Classification Result (Class=4)

This result is crucial for ensuring that the classification model can correctly identify serious fault conditions, such as LLLG faults, which are vital for triggering protective mechanisms and preventing damage to electrical equipment. Similarly KNN classify the underlying causes using Hilbert plot of voltage sag signal.

Comparative Analysis of KNN Classifier Results for Different Underlying Reasons

Normal voltage and current hilbert plot (class 1) displays an elliptical shape, typical of a stable and undisturbed current under normal conditions. The classifier correctly identified as Class 1, indicating normal operating conditions. The consistent elliptical shape suggests smooth operation with no disturbances.

The Induction Motor Starting (Class 2) voltage and current Hilbert Plot displays a spiralling pattern, indicative of the transient increase in current during the motor's start-up phase. The KNN classifier correctly identified as Class 2, corresponding to the induction motor starting condition. The spiral shape reflects the motor's high inrush current and subsequent stabilization as it reaches full speed.

The transformer energization (Class 3) voltage and current Hilbert Plot displays features a unique shape with rapid expansion, typical of inrush current during transformer energization. Accurately classified as Class 3, representing the transformer energization event. The pattern highlights the transient nature of the energization process, marked by a significant inrush current.

The LLLG Fault (Class 4) voltage and current HT plot exhibits a looped structure with pronounced asymmetry, characteristic of severe faults like LLLG. The classifier correctly categorized as Class 4, associated with a three-phase-to-ground fault. The loop indicates a highly disturbed current, typical of a severe fault condition requiring immediate attention.

The KNN classifier effectively distinguishes between various underlying reasons of voltage sags, with each Hilbert plot providing a unique visual signature that aligns with the corresponding classification. The classifier's ability to accurately categorize these conditions ensures reliable monitoring and fault detection in electrical systems.

By exploring these avenues, the methodology of Hilbert plot analysis combined with KNN classification can evolve into a more powerful and versatile tool, further enhancing the reliability and efficiency of electrical systems and beyond.

CONCLUSION

The analysis of voltage sags using Hilbert transform plots for both voltage and current waveforms has proven to be an effective method for distinguishing between various underlying causes. The visual differentiation in the Hilbert plots for different events, such as IM starting, transformer energization, and LLLG faults, provides clear signatures that can be used to classify these disturbances accurately. The successful classification of the normal current waveform, IMS, TE and LLLG fault using the KNN algorithm further validates the reliability of this approach. By accurately identifying the class associated with a normal current waveform, IMS, TE and LLLG fault, the methodology confirms its potential in practical applications for real-time monitoring and diagnosis of power quality issues, thereby enhancing the stability and reliability of electrical systems.

REFERENCES

1. R. Kumar, B. Singh, R. Kumar and S. Marwaha, "Recognition of Underlying Causes of Power Quality Disturbances Using Stockwell Transform," in IEEE Transactions on Instrumentation and Measurement, vol. 69, no. 6, pp. 2798-2807, June 2020.
2. Mahela, Om Prakash, and Abdul Gafoor Shaik. "Recognition of power quality disturbances using S-transform based ruled decision tree and fuzzy C-means clustering classifiers." Applied Soft Computing 59 (2017): 243-257.
3. Aseri, Ramesh, and Ashwani Kumar Joshi. "Stockwell Transform and Hilbert Transform Based Hybrid Algorithm for Recognition of Power Quality Disturbances." In Intelligent Energy Management Technologies, pp. 425-448. Springer, Singapore, 2021.
4. Saxena, D., K. Verma, and S. Singh. "Power quality event classification: an overview and key issues." International journal of engineering, science and technology 2, no. 3 (2010): 186-199.
5. Ma, Yuanqian, Xianyong Xiao, and Yang Wang. "Identifying the root cause of power system disturbances based on waveform templates." Electric Power Systems Research 180 (2020): 106107.
6. Thakur, Padmanabh, and Asheesh K. Singh. "Signal processing and AI based diagnosis of power quality disturbances: A review." In 2015 International Conference on Energy Economics and Environment (ICEEE), pp. 1-6. IEEE, 2015.
7. Mehta, Yogesh, Ravindra Prakash Gupta, and O. S. Lamba. "Recognition of Power Quality Disturbances in Renewable Energy Sources Based Smart Grid Using Stockwell Transform." Journal of Emerging Technologies and Innovative Research (JETIR) 6, no. 5 (2019).
8. Ding, Kai, Wei Li, Pan Hu, Ying Wang, and Jia-ni Xie. "A New Method for Characterizing Voltage Sag Tolerance." In 2019 IEEE Innovative Smart Grid Technologies-Asia (ISGT Asia), pp. 60-63. IEEE, 2019.
9. Pandya, V., Agarwal, S., Mahela, O. P., & Choudhary, S. (2020). "Recognition of Power Quality Disturbances Using Hybrid Algorithm Based on Combined Features of Stockwell Transform and Hilbert Transform" International Students' Conference on Electrical,Electronics and Computer Science (SCEECS). IEEE 2020
10. R. Kaushik, O. P. Mahela, P. K. Bhatt, B. Khan, S. Padmanaban and F. Blaabjerg, "A Hybrid Algorithm for Recognition of Power Quality Disturbances," in IEEE Access, vol. 8, pp. 229184-229200, 2020
11. Erişti, Hüseyin, Özal Yıldırım, Belkıs Erişti, and Yakup Demir. "Automatic recognition system of underlying causes of power quality disturbances based on S-Transform and Extreme Learning Machine." International Journal of Electrical Power & Energy Systems 61 (2014): 553-562.
12. Hajian, Mahdi, Asghar Akbari Foroud, and Ali Akbar Abdoos. "New automated power quality recognition system for online/offline monitoring." Neurocomputing 128 (2014): 389-406.
13. Xie, Shanyi, Fei Xiao, Qian Ai, and Gang Zhou. "Classification of underlying causes of power quality disturbances using data fusion." In 2018 International Conference on Power System Technology (POWERCON), pp. 4118-4123. IEEE, 2018.
14. R. H. Tan and V. K. Ramachandra Murthy, "Simulation of power quality events using Simulink model," in Proc. IEEE 7th Int. Power Eng. Optim. Conf. (PEOCO), Jun. 2013, pp. 277-281.

15. Mishra, Manohar. "Power quality disturbance detection and classification using signal processing and soft computing techniques: A comprehensive review." International transactions on electrical energy systems 29, no. 8 (2019): e12008.

16. Bollen, Math HJ, Irene YH Gu, Peter GV Axelberg, and Emmanouil Styvaktakis. "Classification of underlying causes of power quality disturbances: deterministic versus statistical methods." EURASIP Journal on Advances in Signal Processing 2007 (2007): 1-17.

17. Jandan, F., Khokhar, S., Shaha, S.A.A. and Abbasi, F. "Recognition and classification of power quality disturbances by DWT-MRA and SVM classifier." International Journal of Advanced Computer Science and Applications, 10(3), pp.368-377 2019.

18. Chawda, G.S., Shaik, A.G., Shaik, M., Padmanaban, S., Holm-Nielsen, J.B., Mahela, O.P. and Kaliannan, P."Comprehensive review on detection and classification of power quality disturbances in utility grid with renewable energy penetration". IEEE Access, 8, pp.146807-146830 2020.

19. Beniwal, Rajender Kumar, Manish Kumar Saini, Anand Nayyar, Basit Qureshi, and Akanksha Aggarwal. "A Critical Analysis of Methodologies for Detection and Classification of Power Quality Events in Smart Grid." IEEE Access (2021).

20. Gonzalez-Abreu, Artvin-Darien, Miguel Delgado-Prieto, Roque-Alfredo Osornio-Rios, Juan-Jose Saucedo-Dorantes, and Rene-de-Jesus Romero-Troncoso. "A Novel Deep Learning-Based Diagnosis Method Applied to Power Quality Disturbances." Energies 14, no. 10 (2021): 2839.

21. Mahela, O.P. and Shaik, A.G., 2017. "Power quality recognition in distribution system with solar energy penetration using S-transform and Fuzzy C-means clustering. Renewable energy," 106, pp.37-51.

22. Singh, Utkarsh. "Near-Perfect Time–Frequency Analysis of Power Quality Disturbances." IETE Journal of Research (2020): pp.1-11

23. Aggarwal, Akanksha, and Manish Kumar Saini. "Designed orthogonal wavelet based feature extraction and classification of underlying causes of power quality disturbance using probabilistic neural network." Australian Journal of Electrical and Electronics Engineering (2021): pp.1-11.

24. R. Kumar, S. Marwaha and R. Kumar, "Cause Based Analysis of Power Quality Disturbances in a Three Phase System," 2018 IEEMA Engineer Infinite Conference (eTechNxT), 2018, pp. 1-6.

25. M. Veizaga, C. Delpha, D. Diallo, S. Bercu, and L. Bertin, "Classification of voltage sags causes in industrial power networks using multivariate time-series," IET Generation, Transmission & Distribution, vol. 17, no. 7, pp. 1568-1584, Apr. 2023. doi: 10.1049/gtd2.12765

26. G. Popovic, S. Petkovic, and A. Mihaljevic, "An End-to-End Deep Learning Method for Voltage Sag Classification," Energies, vol. 16, no. 3, pp. 1-24, Feb. 2023.

27. Bonde, G. N., S. R. Paraskar, and S. S. Jadhao. "Review on detection and classification of underlying causes of power quality disturbances using signal processing and soft computing technique." Materials Today: Proceedings 58 (2022): 509-515.

28. Kumar, R., Singh, B., Kumar, R., & Marwaha, S. (2021). Online Identification of Underlying Causes for Multiple and Multi-Stage Power Quality Disturbances Using S-Transform. IETE Journal of Research, 69(6), 3739–3749.

Optimizing Photovoltaic System Integration with LVRT Capability for Enhanced Grid Stability

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ABSTRACT

This paper presents a study on optimization of photovoltaic (PV) system with Low Voltage Ride Through (LVRT) capability and Dynamic Static Synchronous Compensator (DSTATCOM) for grid stability improvement. Linking renewable energy sources, like PV systems, to grid systems has grown significantly, which makes grid stability improvement techniques very important to tackle. LVRT capability is one of the potential and applicable options used in grid stability improvement under PV, nowadays. DSTATCOM can play a frontier role in grid stability when it is used with LVRT because grid stability is one of its important applications because it works with stability and thus can directly affect the grid stability improvement. In this abstract, the summative functions of LVRT and DSTATCOM in grid stability improvement are presented. It is proved in this study that using the two advanced technologies could lead to grid stability improvement indirectly by decreasing voltage fluctuations that have a key role in grid stability and directly by securing the power transfer at the time of grid disturbances. Simulations of the two technologies are also discussed and compared with the system without LVRT and DSTATCOM, which can show the importance of the used control methods and grid-friendly attributes in the integration of PV systems with the grid systems.

KEYWORDS: *Photovoltaic systems, Grid stability, Low Voltage Ride Through (LVRT), Dynamic Static Synchronous Compensator (DSTATCOM), Renewable energy integration, Power grid resilience.*

INTRODUCTION

Over the past two decades, renewable energy sources integration into power systems has had an unprecedented growth. This surge is due to the global need to shift the world from fossil-based power systems towards a sustainable energy use, a reduction on greenhouse gas emissions and an increase in energy security. As a result, the daily production of photovoltaic (PV) systems is rapidly becoming a major part of the generation mix. While [1] they are clean resources that promise abundant energy, the unmistakable increase in PV penetration is presenting grid operation and stability challenges.

The inherent intermittent nature of solar variability and weather impacts make PV generation subject to fluctuations, creating variations in voltage and frequency levels that inevitably cause deviations from normal power quality levels. These events can influence grid stability and reliability, and will require advanced control strategies and grid-friendly features to make them work.

In particular, ensuring grid stability with increasing levels of PV penetration requires the development of Low Voltage Ride Through (LVRT) capability for PV inverters [2]. LVRT allows a PV inverter to remain connected to the grid and continue supplying power. Without this capability, when the voltage in a grid section dips or is momentarily disturbed, inverters will automatically disconnect from the grid. With a significant amount of PV capacity, this disruption can cause widespread blackouts by triggering a chain

reaction known as a 'domino' effect, in which a loss of generation in one section leads to grid disruption in another due to the flow of power through circuit breakers. LVRT mitigates this risk, as it [3] allows inverters to retain grid connection, thus reducing the chance of disruption in other grid sections and stabilising grid operation during the transient event.

Besides the LVRT capability, Dynamic Static Synchronous Compensator (DSTATCOM) [4], which can enhance grid stability by providing rapid reactive power support is also becoming increasingly attractive. DSTATCOM is a fast-responding flexible compensator able to provide fault-current-limiting functions, reactive power support, voltage control and harmonic control. DSTATCOM can provide in-phase reactive power support to match the local load and also out-of-phase reactive power support to compensate for the harmonic current, thereby improving power quality and grid stability.

This synergy [5] between LVRT capability and DSTATCOM integration ensures a holistic approach to solve grid stability issues due to high-penetration PV systems. An integrated PV plant design with advanced control algorithms and real-time monitoring coordinate PV inverters and grid-supportive devices to operate without and with any disturbances in a grid environment.

In this paper [6], the integration of LVRT capability with PV system is presented, to improve the stability of the grid. Based on available studies from literature; simulation, and case studies; benefits and drawbacks of PV system with LVRT integrations will be explained. Furthermore, combination of LVRT capability with DSTATCOM integrations and their synergic effects towards stability and grid resiliency will also be examined.

Real challenges in integrating PV systems into the grid is maintaining stability

Scaling up and integrating PV systems into the existing grid is complex, and stability is of paramount importance. Here is an outline of why stability is an important issue and what that means:

Variability and Intermittency: PV are also intermittent power sources that depend on the amount of sunlight, which is variable throughout the day, year and region [7]. The resulting power generation fluctuates and creates voltage and frequency deviations that must be balanced for the grid to retain stability.

Voltage Regulation: When PV systems are fed into the grid, it will cause fluctuation of the system voltage, which may exceed the present design limits of the grid [8]. The voltage profile along the distribution system networks could be seriously influenced by the high penetration of PV systems. Over-voltages could occur at low load point of a system when solar production is high.

Grid Infrastructure and Capacity: In fact, most of the installed grids were created for centralised power generation sources such as large power plants to provide electricity through a transmission and distribution network [9]. In order to integrate decentralised and volatile aspects of PV systems, the grid infrastructure has to be augmented by adding new transmission lines or upgrading existing transformers and substations to deal with different dynamics of power flow.

Protection Coordination: Distributed generation through PV means that the protection schemes of the grid are no longer bilateral, as power can now flow in multiple directions. The existing protection devices might not detect faults anymore or malfunction due to changed flows [10], which can lead to safety risks or damage equipment.

Frequency Control: All readers are aware that one of the most important aspects of grid management is frequency stability. Large power plants provide an inertial contribution towards this through their inertia. PV panels are not accompanied by inertia by default, and those connected through an inverter do not provide the same inertial contribution. This [11] lack of inertia from PV can lead to faster, more 'noisy' frequency changes, and can cause more trouble in maintaining stable grid frequency (for example, at high penetration levels).

Real-Time Monitoring and Control: Variability and instability are dealt with by adding advanced monitoring and control systems to grids – in the form of smart meters, sensors embedded in power systems and grids, and advanced forecasting systems [12] to predict power output from PV, and allow grids to respond accordingly. The grid must be able to capture and utilise real-time

data and controls to balance supply and demand, and grid stability.

Regulatory and Market Structures: Further, integrating PV systems challenges existing regulatory and market structures, all built on the premise of centralised generation, and requires new regulations and market mechanisms for reflecting distribution generation sources, including fair pricing and investment in grid infrastructure upgrades.

Objective

Integrating high-penetration photovoltaic (PV) systems into electrical grid can enormously inject unstable power elements into the grid system, both on grid and circuit levels, which threat a lot to power quality and grid stability significantly. The main concern of this article is to provide an overall view of the related problems and feasible measures. Following are the author's objectives:

i. Understanding the grid integration challenges: This research is set to deliver a truly deep grasp of the challenges of grid integration of high-penetration PV, covering related technical, infrastructural challenges, such as solar variability, voltage issues, grid integration issues etc.

ii. Survey of Multifunctional Inverters, LVRT Capability, and DSTATCOM: This review will explore the possible advantages and roles of multifunctional inverters, low-voltage ride-through (LVRT) capability and distribution static compensators (DSTATCOM). These technologies will facilitate improved PV performance and efficiency in a scenario highly penetrated by PVs. Multifunctional inverters convert DC electricity to AC but, at the same time, provide services of reactive power control and harmonic compensation to the grid to stabilize it.

iii. Reviewing Advanced Power Control Methods: Detail the various advanced power control methods that can be used, such as Controller for Maximum Power Point tracking, Reactive Power for controlling the inductive Reactive component, Voltage for controlling output voltage from the inverter, and Harmonic for compensating and avoiding the harmonic generation from Photovoltaic system. Effective implementation of these methods is necessary to improve the Photovoltaic system operation and to be in accordance with current grid operations.

iv. Recent Advancements and Future Research Directions: At the end of the review, the advancements in the aforementioned control techniques, as well as the future research directions, will be discussed. Consideration of new technologies that will be developed, better methodologies for already developed technologies to increase their efficacy, and new approaches to overcome the persisting PV integration problems with new technological advancements would be included in this section.

Achieving these objectives will enable the research to contribute important insights for integrating sophisticated power control techniques for high penetration opportunities in a selection of different types of PV systems, enabling power generating and distribution to become more resilient and sustainable in the future, which is now more urgent than ever before as communities strive for clean renewable energy systems with high reliability.

LITERATURE REVIEW

A comprehensive of literature related to the incorporation of high-penetration photovoltaic (PV) into the electric power grid shows a variety of research, technology innovations and practical application of the power system. This study provides a comprehensive view of the technologies, implementation, and control solutions to high PV penetration on the electric grid.

One of the big issues pointed to in the literature is grid stability, which is intertwined with the variability of PV systems. Solar power is an intermittent source of energy generation. The fluctuations of power generation could cause tremendous volatility in the grid frequency and voltage. Studies reveal that a significant increase in these volatilities above reference levels could compromise the power supply reliability and potentially lead to severe damages to grid infrastructures if not mitigated properly. The issue of variability underlines the need for an adaptive grid management that could detect rapid changes in levels of energy generation.

According to [13], multifunctional inverters are the key technology to tackle these 'integration challenges' in ways that go beyond simply converting DC solar energy into AC grid-quality power supply: Multifunction inverters provide vital services for frequency regulation, voltage support, and load balancing, and these functions are central to providing active grid support and the stability that makes the grid resilient and reliable.

Finally, around a third of the studies focused on yet another widely accepted EU standard, that is, the inverter's low-voltage ride-through (LVRT) capabilities. LVRT refers [14] to an inverter's ability to continue operation and inject power into the grid during temporary voltage dips, thereby providing grid support and helping to stabilise it. In several case studies, detailed by Zhang et al, LVRT-capable inverters were installed and shown to prevent potential disturbances due to sudden voltage dips, with many documented cases.

Distribution static compensators (DSTATCOM) are also widely discussed in the literature for enhancing power quality in systems with high PV integration by improving power quality factors such as voltage sag, swell and flicker, which are a main problem in distribution networks with high penetration rates of intermittent renewables [13]. Gupta and Kumar (2017) present empirical evidence of the effective use of DSTATCOMs for maintaining the stability of voltage levels during PV curtailments, thus improving the power quality and assisting with the grid integration of PVs.

MPPT is one of the advanced power controller techniques that provide better performance for PV systems by maximising the energy yield by operating at Pmaz for different solar irradiance profiles and for different temperatures. MPPT techniques [14] work on the principle of perturbation and observation by moving the working point of a PV panel up and down within its I-V curve. It can be further enhanced through the utilisation of mature mathematics, such as advanced optimisation. Many studies have been done using MPPT, for example, Lee and Chen (2019), which revealed that MPPT can enhance the efficiency of PV installations, especially where solar irradiance fluctuates significantly.

The management of reactive power by PV systems is another area of noticeable improvement, helping to keep voltage stable across the grid. For example, [15], when as entire grid area is covered by clouds suddenly, solar power generation would likely drop massively. Without the flexibility of the conversion technologies and stabiliser devices, the change could lead to voltage instability. Reactive power control technology is therefore of paramount importance for attaining high PV penetration while systems retain stable operations Maintaining voltage stability through reactive power control technologies.

The ability of modern PV inverters to regulate voltage is another important aspect of grid integration [16]. This improves the grid's operation by preventing adverse variations in grid voltage levels, which can have an effect on the grid infrastructure as much as on the consumers of it. Some researchers have concluded that including voltage regulation functions in PV inverters is helpful in minimising the risk of these voltage-related problems.

Harmonic compensation is another essential function that these sophisticated inverters deliver. PV systems, like most pieces of electronics equipment, produce electrical harmonics when connected to the grid [17]. In some circumstances, the harmonics can degrade power quality and efficiency. Harmonic compensation techniques are used to minimise these effects. The authors Patel and Agarwal (2018) argue that such techniques and the use of harmonic compensated inverters improve the efficiency of systems, and prolong the life of electrical devices because they are less stressed by poor power quality.

So, even though these new smart and multifunctional control technologies have an abundance of advantages, there might also be some inherent limitations in these technologies [10]. For example, some of the more sophisticated grid control and filtering devices, such as the aforementioned multifunctional inverters and DSTATCOM devices, can be very costly, especially for smaller and rural grid operations. The technical and logistical challenges of integrating these technologies into already existing grid infrastructures can also be exorbitant.

Additional research goals suggested in these studies include the need for achieving lower costs and more easily implemented technology integration. Standard, global regulatory frameworks and guidelines are also needed to guide local acceptability, regulatory approval and operation.

METHODOLOGY

Low Voltage Ride Through and Dynamic Static Synchronous Compensator are two techniques used to improve the stability of a network that might cause a grid collapse. We assessed the performance of both methods using a grid connectivity simulation modelled in MATLAB/Simulink. Our model consists of photovoltaic system, comprising of solar panels and different inverters and control systems that are connected to the grid. The solar panels are modelled using the equation P= G*A*η, where P denotes power, G is irradiance, A is the area, and η

η represents efficiency. The grid simulation incorporates standard power distribution components, including transformers, power lines represented by the impedance Z_{line} = R + jX (where R and X are the resistance and reactance, respectively), and dynamic load models.

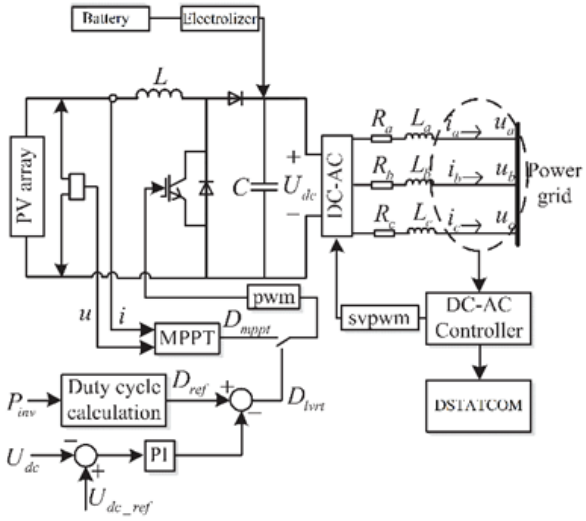

Fig. 1 : System structure diagram of active LVRT and DSTATCOM strategy

The proposed design is a grid-connected photovoltaic (PV) system with each of the 235 strings having 16 connected modules in series. The electrical characteristics of the system setup are calculated to be a maximum current of 1889.4 A (8.04A per module x 235 strings), voltage of 796.48 V (49.78V per module x 16 modules) and a total dc output power of about 1.5 MW (1889.4A x 796.48V). The open-circuit voltage of PV array is 960 V (60V per module x 16) and short-circuit current is 2011.6A (8.56A per module x 235 strings).

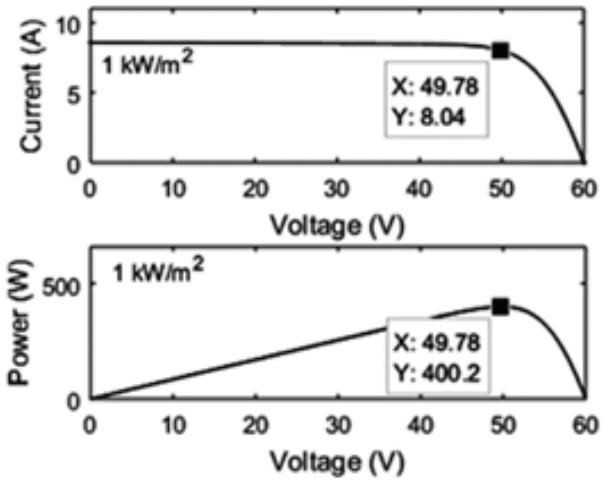

Fig. 2 : Characteristics curve of proposed PV module

The dc-link voltage in the system is 800V, which is equal to the maximum power point output voltage of the PV modules. The calculation is confirmed through a MATLAB/SIMULINK model of the proposed PV array, as depicted in Figure 2.

Table 1 : Parameters of PV cell

sSpecifications Values	
Maximum power (Pmax)	400 W
Maximum power point voltage (Vmpp)	49.78 V
Maximum power point current (Impp)	8.05 A
Open circuit voltage (Voc)	60 V
Short circuit current (Isc)	8.56 A
Cell number per module (Ncell)	96
Temperature coefficient of open circuit voltage (αv)	–0.367◦C
Temperature coefficient of short circuit current (αi)	0.043◦C
Series resistance (Rse)	389.9 Ω
Parallel resistance (Rsh)	0.33 Ω
Ideally factor of diode (n)	1.02

In Low Voltage Ride Through (LVRT) mode, the PV system encounters imbalances and transients affecting

both the dc-side voltage and the ac-side current. A novel control strategy, integrating Proportional-Integral (PI) and P&O techniques along with Indirect Power Transfer (IPT), ensures that the PV power plant remains operational during fault conditions. This approach effectively manages overvoltage and overcurrent situations, adhering to the Malaysian grid code requirements. Normally, when the grid voltage stays within 90% to 110% of its rated value, the system operates in standard mode. However, deviations from this voltage range trigger the switch to LVRT mode.

During fault conditions or voltage sags, it is crucial to adjust the reactive current setting so that the inverter can inject enough active power to restore the grid voltage to acceptable levels, as specified by LVRT protocols. For the control methods applied in this system, the reactive current is intentionally set to zero to focus on stabilizing active power output. Graphical representations detailing the performance of the system under these conditions—specifically showing PV side voltage and power, along with grid side active and reactive power—are provided to demonstrate the efficacy of the inverter control during both symmetrical and asymmetrical faults on the grid side. These visual data help illustrate the robust response and reliability of the system under varied and challenging operational scenarios.

The harmonic loss in a smart microgrid can be reduced by using a number of sophisticated technologies and control strategies. The Distribution Static Synchronous Compensator (DSTATCOM) injects compensating currents that are in phase and of equivalent magnitude to the harmonic currents

$I_{comp} = -I_{harmonic}$ Using what's known as the Instantaneous Reactive Power Theory (IRPT), the DSTATCOM constantly monitors the load current, extracts the harmonic components, and generates the respective compensating currents in real time. LVRT is a feature in PV inverters, which assists in riding through low voltages (scenarios where the grid voltage dips slightly) while continuing to inject reactive power into the grid and support the voltage. This feature also helps reduce harmonic content.

Indeed, multifunctional inverters with Voltage Source Converter (VSC) control are key assets for harmonic mitigation. VSC inverters use PWM to produce, when used as grid-connected devices, a smooth sinusoidal output, and may also be implemented as active filters. PWM ensures that the magnitude of the harmonic currents injected into the grid by active inverter loads (for example, power-electronic devices and DC-coupled microgrids) may be minimised. The inverter output current may be written as

$I_{inv(t)} = I_{fund(t)} + I_{filter(t)}$, where $I_{fund(t)}$ is the fundamental current and $I_{filter(t)}$ is the filtering current. Advanced control algorithms, such as Model Predictive Control (MPC), further improve performance by predicting

RESULT AND DISCUSSION

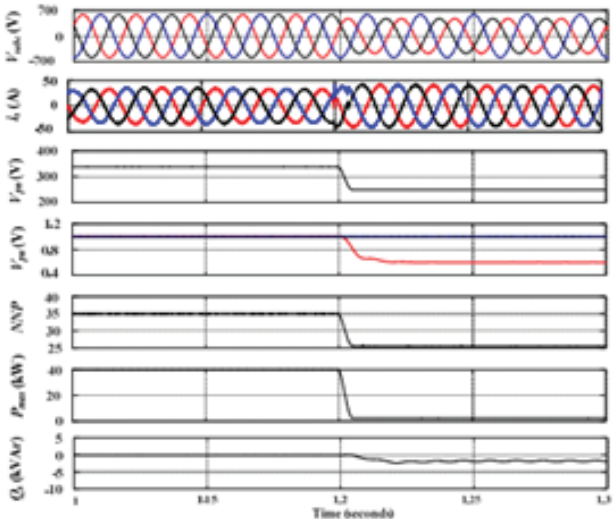

Fig. 3 : Simulated results for L-G fault in the grid side network

The system was simulated under normal operating conditions, with the results displayed in Figure 1. During these conditions, the inverter operated smoothly, producing an output voltage of 796.4 V and approximately 1504 kW of power from the PV power plant, while maintaining standard grid parameters of 33 kV and grid power of 1 MW. Under normal conditions, the maximum possible active current was injected, and the reactive current injection was zero. However, these parameters deviated from normal during fault conditions or voltage sags. At such times, the inverter would typically disconnect from the grid, but with the

implementation of novel control strategies, it was able to switch to Low Voltage Ride Through (LVRT) mode and maintain connection. Consequently, the dc-link voltage prompted the PV plant to operate at its maximum point, equivalent to the open-circuit voltage of the PV panels.

During these incidents, substantial active and reactive current support was necessary to stabilize the grid. The control strategies effectively managed to inject the required reactive current, thereby mitigating the disturbances. While the recovery to pre-fault voltage, current, and power levels took longer during the three-phase fault, the recovery from the line-to-line fault occurred more swiftly, demonstrating the varied effectiveness of the proposed control approaches under different fault conditions.

CONCLUSION

An optimisation study of a photovoltaic (PV) system with Low Voltage Ride Through (LVRT) capability and Dynamic Static Synchronous Compensator (DSTATCOM) demonstrates the large potential for grid stability enhancement. The advanced technologies boost grid stability through the capability of the PV system handling grid disturbances and operating under various faults, including voltage sags. Moreover, the PV system can provide reactive power to support the grid. Firstly, the simulation at nominal conditions exhibits the current of each converter. Under the control of the general control unit, the active and reactive powers are delivered to the grid based on the predefined dynamic programming.

A simulation of under-voltage conditions concludes that by turning on LVRT, the PV system is able to keep itself on the grid and normalised power transfer, while without LVRT, the power transfer is prevented.

Furthermore, the transient simulation reveals the voltage enhancement by inserting DSTATCOM, if not, the voltage would oscillate.

Going forward, further improvements could include developing more advanced control algorithms for dynamic load and voltage sag mitigation to handle a wider range of grid conditions. Finally, the approach could be extended to other renewable energy systems such as wind turbines and their control. Actual lab- and field-scale pilot testing of the technologies could be performed and their performance as well as real-world challenges would be gathered. Further work could also look at new energy storage technologies; the main objective would be to improve the resilience and efficiency of grid-connected PV. Modern grid infrastructures could be explored; finally, economic and regulatory studies could be performed to understand the technical feasibilities and economics of the solutions under a range of different grid conditions that span across different regions and situations in the market.

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AUTHOR CONTRIBUTION

This collaborative work on the optimisation of Photovoltaic (PV) Systems having (LVRT) low voltage ride through capabilities and DSTATCOM (Dynamic Static Synchronous Compensator) for grid stability enhancement was undertaken by the authors, 1 and 2. Author 1 was responsible for conceptualising the project, integrating the LVRT and conducting the simulations, data analysis and writing part of the manuscript. Author 2 was involved in integrating the DSTATCOM and its optimisation and also wrote the remaining part of the manuscript after conducting the literature survey.

REFERENCES

1. T. E. K. Zidane, A. S. Aziz, Y. Zahraoui, H. Kotb, K. M. Aboras, Kitmo and Y. B. Jember, Grid-Connected Solar PV Power Plants Optimization: A Review, vol. 11, 2023.
2. W. Zhou, Y. Zheng, Z. Pan and Q. Lu, Review on the battery model and SOC estimation method, vol. 9, 2021.

3. H. Zheng, F. Xu, Q. Shu, C. Wang and Q. Zhou, "Estimation of harmonic impedance and harmonic contribution with harmonic complex power in the absence of harmonic phase angle," IET Generation, Transmission and Distribution, vol. 17, no. 1, 2023.

4. W. Yuan, X. Yuan, L. Xu, C. Zhang and X. Ma, "Harmonic Loss Analysis of Low-Voltage Distribution Network Integrated with Distributed Photovoltaic," Sustainability (Switzerland), vol. 15, no. 5, 2023.

5. Y. T. Wassie and E. O. Ahlgren, "Performance and reliability analysis of an off-grid PV mini-grid system in rural tropical Africa: A case study in southern Ethiopia," Development Engineering, vol. 8, 2023.

6. X. Wang and F. Blaabjerg, "Harmonic Stability in Power Electronic-Based Power Systems: Concept, Modeling, and Analysis," IEEE Transactions on Smart Grid, vol. 10, no. 3, 2019.

7. P. Unruh, M. Nuschke, P. Strauß and F. Welck, "Overview on grid-forming inverter control methods," Energies, vol. 13, no. 10, 2020.

8. K. H. Tan, M. Y. Li and X. Y. Weng, "Droop Controlled Microgrid With DSTATCOM for Reactive Power Compensation and Power Quality Improvement," IEEE Access, vol. 10, 2022.

9. U. Subramaniam, S. Vavilapalli, S. Padmanaban, F. Blaabjerg, J. B. Holm-Nielsen and D. Almakhles, "A hybrid PV-battery system for ON-grid and off-grid applications-controller-in-loop simulation validation," Energies, vol. 13, no. 3, 2020.

10. R. Sharma, A. Zakerian and M. Karimi-Ghartemani, "Local Controller for an Autonomous Grid-Supportive Battery Energy Storage System," IEEE Transactions on Power Electronics, vol. 37, no. 2, 2022.

11. T. Salameh, A. K. Hamid, M. M. Farag and E. M. Abo-Zahhad, "Experimental and numerical simulation of a 2.88 kW PV grid-connected system under the terrestrial conditions of Sharjah city," Energy Reports, vol. 9, 2023.

12. D. K. Rukmani, Y. Thangaraj, U. Subramaniam, S. Ramachandran, R. M. Elavarasan, N. Das, L. Baringo and M. I. A. Rasheed, "A new approach to optimal location and sizing of DSTATCOM in radial distribution networks using bio-inspired cuckoo search algorithm," Energies, vol. 13, no. 18, 2020.

13. D. J. Rincon, M. A. Mantilla, J. M. Rey, M. Garnica and D. Guilbert, An Overview of Flexible Current Control Strategies Applied to LVRT Capability for Grid-Connected Inverters, vol. 16, 2023.

14. I. Murzakhanov, G. M. Vishwanath, K. Vemalaiah, G. Prashal, S. Chatzivasileiadis and N. P. Padhy, "A novel decentralized inverter control algorithm for loss minimization and LVRT improvement," Electric Power Systems Research, vol. 221, 2023.

15. O. P. Mahela, N. Gupta, M. Khosravy and N. Patel, "Comprehensive overview of low voltage ride through methods of grid integrated wind generator," IEEE Access, vol. 7, 2019.

16. X. Liu, G. Chang, J. Tian, S. Li and C. Chen, "Regrouping strategy of retired batteries considering SOC consistency," Energy Reports, vol. 8, 2022.

17. Q. Lagarde, B. Beillard, S. Mazen, M. S. Denis and J. Leylavergne, Performance ratio of photovoltaic installations in France: Comparison between inverters and micro-inverters, vol. 35, 2023.

18. A. Khursheed, M. Ilyas, K. M. Rafi and A. S. Azad, "A Novel Modified PSO Algorithm to Optimise the PV Output Power of Grid-Connected PV System," SSRG International Journal of Electrical and Electronics Engineering, vol. 10, no. 7, 2023.

19. K. Hasan, S. B. Yousuf, M. S. H. K. Tushar, B. K. Das, P. Das and M. S. Islam, Effects of different environmental and operational factors on the PV performance: A comprehensive review, vol. 10, 2022.

20. A. Harrag and S. Messalti, Variable step size modified P&O MPPT algorithm using GA-based hybrid offline/online PID controller, vol. 49, 2015.

21. Y. Gu and T. C. Green, "Power System Stability With a High Penetration of Inverter-Based Resources," Proceedings of the IEEE, vol. 111, no. 7, 2023.

22. Z. M. S. Elbarbary and M. A. Alranini, "Review of maximum power point tracking algorithms of PV system," Frontiers in Engineering and Built Environment, vol. 1, no. 1, 2021.

23. G. Dileep, "A survey on smart grid technologies and applications," Renewable Energy, vol. 146, 2020.

24. J. H. Chen, K. H. Tan and Y. D. Lee, "Intelligent Controlled DSTATCOM for Power Quality Enhancement," Energies, vol. 15, no. 11, 2022.

25. S. Chakraborty, S. Mukhopadhyay and S. K. Biswas, "Optimal Placement of PV-DSTATCOM Based EV Charging Stations with Dynamic Pricing," IEEE

Transactions on Industry Applications, vol. 59, no. 6, 2023.

26. J. M. Akanto, M. R. Hazari and M. A. Mannan, "Lvrt and stability enhancement of grid-tied wind farm using dfig-based wind turbine," Applied System Innovation, vol. 4, no. 2, 2021.

27. S. M. Ahsan, H. A. Khan, A. Hussain, S. Tariq and N. A. Zaffar, "Harmonic analysis of grid-connected solar PV systems with nonlinear household loads in low-voltage distribution networks," Sustainability (Switzerland), vol. 13, no. 7, 2021.

28. ahmed Ali, R. A. E.-K. El-Kammar, H. F. A. Hamed, A. A. Elbaset and A. Hossam, "A developed IoT technique and P&O-MPPT to enhance the output power of solar cell systems," Journal of Engineering Research, vol. 7, no. 5, 2023.

29. J. Ahmed and Z. Salam, "An improved perturb and observe (P&O) maximum power point tracking (MPPT) algorithm for higher efficiency," Applied Energy, vol. 150, 2015.

30. G. A. Adepoju, S. A. Salimon, I. G. Adebayo and O. B. Adewuyi, "Impact of DSTATCOM penetration level on technical benefits in radial distribution network," e-Prime - Advances in Electrical Engineering, Electronics and Energy, vol. 7, 2024.

31. A. A. Abdelsalam, S. S. M. Ghoneim and A. A. Salem, "An efficient compensation of modified DSTATCOM for improving microgrid operation," Alexandria Engineering Journal, vol. 61, no. 7, 2022.

Review on Application of Optimization Techniques for Better Agriculture

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ABSTRACT

Water is the prime life sustaining finite natural resource. Irrigation is vital input for crop growth and better production. Irrigation Water Management is an inter-disciplinary study. Besides Irrigation Engineers, it has been studied by economists, agronomists, geographers, sociologists, planner and administrators. The crevice between the water system potential made and utilized ought to be minimized and agriculturists empowered receiving superior water system hones. The critical review of literatures related to application of various Optimization Techniques in the field of Agriculture Management have been discussed to assess the contributions to this field of research and scope for the future.

KEYWORDS: *Agriculture management, Optimization technique, Classical algorithm, Deterministic dynamic programming.*

INTRODUCTION

Water asset is one of the foremost vital resources of a nation. Other than it's utilize for the residential segment, water is crucially required for rural generation. Irrigation is depicted as the method of supplement the shortage sum of water to the Agrarian field to dodge the circumstances like diminish in efficiency and blurring absent of crops, which lead to conditions of starvation and fiasco (Reddy et al. (2019), Janbandhu et al. 2018). This work aims to prepare a strategic framework for assessing and optimising the irrigation water use on the water regime, especially in the command areas falling in the arid regions using various optimization techniques To realize the target the literary works related to the topic have been conducted. Assessment the of different optimization techniques such as (meta-heuristic procedures such as Swarm-Intelligence-Based Algorithms (Particle swarm optimization (PSO), Insect Colony Optimization, Cuckoo look and Developmental Calculation Hereditary calculation, DE etc.) to reach at the ideal trimming design. A part of things are contributed with the application of innovations. Keeping an eye on all of the over viewpoints, the show article centred on proposing the procedure for surrounding the arrangement, and points of interest of execution.

MATERIAL AND METHODS

The survey of literature indicates that various authors have contributed to the field of optimal irrigation management, the detailed mention being presented in the relevant section of this Article. Lot of things are contributed; but a lot of works to be done to alleviate the real life problems with the application of technology. A critical review of literatures related to Agriculture management and Optimization Techniques with the use of various Algorithms have been done to assess the work done in this field of research.

Agriculture Management

Farmers are the backbone of a country and due to their contribution, world can eat. The decision makers always try to give a better option than the previous one to give maximum profit to the farmers. There are so

many methods, models, technology adopted to increase the yield of land and give more information about cropping and give us idea to get a new technique to get maximum profit. The importance of studies on proper Agriculture management were felt and it was addressed in early 60s and 70s. A specific hydrologic model for a stream-alluvial aquifer system for maintaining rules and regulations to maximize the productivity of water was also suggested (Burt (1964 and Hall and Dracup (1970). Linear programming models were applied for development of River basin by applying zero order decision rules for the models.

The main aims of the above studies were to find out what would be the management options in crisis period. These were also helpful in knowing the future research in the field of Agriculture water management to develop decision-support-system (DSS) for water management based on river catchment with the open database to suggest a cropping pattern. A strategy for crop management was developed considering the climate forecasting (Royce et al. (2001)). Model for reservoir systems to know the irrigation demand in the study area required to develop a decision-support tool. It is needed to avoid short term crisis as well as long term sustainability. Different issues related to water planning and management considering environment impact were also discussed. A combined model of numerical simulation and linear optimization were suggested to help in maintaining a balance between stream flow water and groundwater pumping, groundwater recharge and discharge (Wrachien and Fasso (2002), Barlow et al. (2003) and Karamouz et al. (2005). Models were proposed as per a combination of both the simulation-optimization model using artificial neural network for a regional near real aquifer systems in a hypothetical condition (Rao et al. (2004), Velázquez et al. (2006)). Agriculture management is a vast field of research. Some of the interesting works are also reported by many authors stochastic irrigation scheduling algorithm to increase the farm profit Brown (2007), Interactive Information System (IIS) to facilitate the operation and management of the command area development and to increase the irrigation efficiency Pervez (2008). Multi criteria decision analysis (MCDA) for ranking of alternative is also a suitable method where these decision rules are to examine them in systematic way. An integrated soil management approach which can be planned for complex deficit agricultural and to improve water resources using LINDO optimization. (Vivekanandan, et al. (2009) and Xu and Tung (2009), Montazar et al. (2009). The interactions between surface water and groundwater with the available alternatives of sources of water were discussed using GIS, Mod flow and U-code software collectively applied a stochastic programming for groundwater pumping and artificial recharge which could fulfil the farmers' expectations and cropping decisions involved in any phase of farming (Marques et al. (2010), Chang et al. (2010) Brown et al. (2010), Boustani .F and Mohammad .H (2010). Bejranonda et al. (2011). Safavi and Alijanian (2011), Kazmi et al. (2012),Singandhupe et al. (2012)). The Artificial Intelligence method is applied in solving certain issues of Irrigation management. Discrete PSO algorithm, fuzzy inference system (FIS) and The Artificial Intelligence method are also applied to develop n multi-objective optimization model to increase the net benefits.(Chang et al. (2013),Khan et al. (2014), Lalehzari et al. (2015) Baky (2010), Amini (2015), Singh et al. (2015)). The FIS model was helpful in the sense that more accurate knowledge could be incorporated in the model and it gave an alternative plan to obtain the conjunctive policies. Performance of drip irrigation systems is studied using the parameters such as discharge, field and design emission, uniformity (EUd) and statistical uniformity coefficient to predict the groundwater fluctuation. The model could give various maps defining the properties of aquifer by analysis of spatial and temporal variation of water table (Arya (2017) and Vasconcelos et al. (2017)). Use of Artificial Intelligence Techniques and linear regressions Technique to ensure better return from the farmland were also suggested. (Rath and Swain (2018) and Zhang et al. (2019).

The critical review of the literatures reveals that an integrated Agriculture management should be done at micro and macro level, which should include the management of agricultural land, fertilizers, pesticides, water availability, cost of water etc. The Bench-Marking Method ought to be connected to bring advancement in all the over parameters. Advance it is recommended that, appropriate water administration for water system utilize ought to be focused on to utilize the water system

water in an economical way to upgrade edit surrender for superior benefits of ranchers.

Classical Algorithm

The Agriculture management very often deals with the many complex situations, which are having multiple objectives and constraints. Optimization is an art in finding the best possible outcome for a problem considering the available limitations. Many optimization techniques are available such as Linear (LP) and Stochastic Linear Programming (SLP), Deterministic Dynamic (DDP) and Stochastic Dynamic Programming (SDP), Meta-heuristic and Evolutionary Algorithms, Swarm-Intelligence Algorithms, etc. Each technique has its own advantages and disadvantages. There is no globally accepted technique which would be acceptable everywhere. Conventional optimization techniques such as Linear Programming (LP), Dynamic Programming (DP), and Non-Linear Programming (NLP) rely on predefined, deterministic procedures to tackle optimization challenges. Over the years, LP has found extensive use in solving various reservoir-related problems. In order to manage reservoirs with multiple purposes, including water supply and hydropower generation. LP enables the simultaneous optimization of these objectives, considering various constraints and trade-offs to optimize the operation of reservoirs specifically for hydropower generation. LP helps in determining the most efficient use of water resources to maximize hydropower output while adhering to operational constraints. (Chow and Windsor (1972) and Mohan and Rajpure (1992). LP models are also used to optimize the operation of multi-reservoir systems. These systems may involve interconnected reservoirs, and LP helps in coordinating their operations to meet various demands efficiently. LP techniques have been applied to estimate water yield from both single and multiple reservoir systems to predict the water availability from these reservoirs, which is crucial for water resource planning and management. The use of LP in these applications provides a systematic and mathematical approach to optimize the allocation and operation of reservoirs, leading to more efficient and sustainable water resource management. These techniques can help balance competing objectives and make informed decisions while considering various constraints and uncertainties in water systems. The popularity of LP in these applications is attributed to its advantages, including the availability of user-friendly software, its straightforward nature, and its ability to handle large-scale linear problems while providing globally optimal solutions under certain assumptions. However, LP has limitations as it requires both the objective functions and constraints to be linear. This linear model formulation may not always accurately represent complex real-world problems, and simplified relationships may yield only approximate solutions.

Linear Programming

Linear Programming is an important and the widely discussed optimization technique. It can be applied for to develop a relation between inflows and storage at different conditions (Dorfman (1962)). To regulate the release in each month for power production and irrigation and to determine the optimal operation policies for a low flow augmentation cum flood control reservoir. The real time reservoir operation for minimization by using Linear Programming (LP) was formulated by the constraints used for the LP model formulation were flow at downstream control flood control point. Liner programming problem can be applied for decision making in agricultural benefits. (Young (1967)). It was concluded that even if the flow penalty was known only within a range, the optimal policy could be determined (Aladulkader et al. (2012),Singh (2014)) the method of mixed-integer linear programming is useful for allocating irrigation water to maximize the farm income. Linear Programming is simple and many readily available software. It can also provide global optimal solutions, if certain conditions are assumed. The drawbacks of this technique is that both the objective and constraints should be linear. So the model is also linear in nature. Hence, this programme is unsuitable to solve and to get feasible solutions for the real world complicated and multi objectives problems.

Stochastic Linear Programming (SLP)

This algorithm is simple, easily available and user-friendly. This technique helps in activity analysis, planning and identifying the constraints. It is good at making predictions. It can be applied in industrial application, Reservoir Operation. Water management and water resources allocation. (Muhammad et al. (2014). Chen et al. (2018)

Non-linear Programming (NLP):

Nonlinear programs such as Sequential quadratic programming (SQP) and augmented price method (APM) methods can be used for solving optimization problems. It is used for the systems having both linear and nonlinear constraints. The whole system has variables having equality and inequality relationship. It can be applied to determine the benefit as well as risk for reliability concern of flood and drought by considering the random inflow and demand in the continuity equation (Barros et al. (2003), Devamane et al. (2006)). The solution of a problems based on NLP based methodologies can suggest an accurate and satisfactory meaningful solutions with a flexibility in constraints. As the result of which NLP is applied as an effective tool in the development of Agriculture.

Deterministic Dynamic Programming (DDP)

This method can be applied for finding optimal reservoir operation policy by using least square regression and taking inputs likes inflows, release and storage for a single reservoir. It is required to maximize the net income from irrigation better the flood control, hydro power generation, water quality control and water supply (Young (1967). Davidsen et al. (2015). Mansouri et al. (2017). Saadat et al. (2017)). Deterministic dynamic programming is a well-organized programe fit to use in the process of irrigation management. As it can be applied efficiently for multi-stage or sequential decision process having linear or non-linear problems with discrete or continuous variables.

Stochastic Dynamic Programming (SDP)

This algorithm which was basically the extension of constrained Dynamic Programming to the area of stochastic reservoir operation. The model is applicable to any type of reservoir configuration and tested for a single reservoir and multi reservoir hypothetical systems, (Trezos and Yeh (1987), Braga et al. (1991). In case of multiple storage reservoirs it is impractical to use backward dynamic programming. Because the basic difficulty arises from it is that it proceeds from month wise data with only one flow transition probability. (Raman and Chandramouli (1996)). Stochastic dynamic programming can be applied for a single-objective optimization approach under specified constraints. This target oriented programme can be applied to non-linear, dynamic outcomes which are associated with stochastic risk. Irrigation requirements and crop management are the stochastic process. This optimization technique can be applied efficiently for the development tools to manage quality of irrigation water. It is also useful to increase farm income. (Kumar et al. (2010). Rosyadi (2021))

Meta-heuristic Algorithm

The meta-heuristic algorithms are inspired by nature. Complex and multi objective problems can be solved efficiently applying this Technique. But sometimes they take more time to give optimum result. The convergence rate is high as compare to other methods. Artificial neural networks, fuzzy logic, etc. are the examples of meta-heuristic algorithms'

Cuckoo Search :(CS)

Application of Cuckoo Search Technique in development of water recourses is found in various literatures. This type of application seems to be unique. The Techniques involved were Cuckoo Breeding Behaviour and Levy Flights of Cuckoo Search, Validation, Standard Test Function, Stochastic Test Function, Simulation and Comparison of Cuckoo Search. (Yang and Deb (2010), Rath et al., 2016; Pankaj et al., 2020; Upadhyaya and Upadhyaya, 2017) have demonstrated that the Cuckoo Search Algorithm (CS) outperforms traditional approaches in various applications, such as developing improved cropping patterns for different seasons and designing efficient water distribution systems . To Genetic Algorithms (GA) and Particle Swarm Optimization (PSO), CS is a population-based algorithm. However, CS incorporates elements of elitism and selection akin to those used in Harmony Search. What sets CS apart is its efficient randomization process, characterized by heavy-tailed step lengths, allowing for the possibility of large steps. CS also involves fewer parameters compared to techniques, like GA and PSO, making it highly adaptable. Consequently, CS can be extended to various meta-population algorithms. It has found practical applications in fields such as irrigation management, addressing various sub-components of complex problems in this domain.

Artificial Neural Network (ANN)

Artificial neural network is used an optimization tool. It is same as neuron system of our brain. It is having some neurons which are interconnected with each other by links and having some weight. ANN can be applied for the deterministic dynamic program results by considering the reservoir release, storage, inflow etc. (Raman and Chandramouli (1996)). The output of ANN is better than the results of stochastic dynamic programming and multiple linear regressions programming. (Coulibaly et al. (2000), Chandramouli and Raman (2001)). A neural network model can be applied for forecasting variation of stages in reservoir level using the Back propagation algorithm. (Ashaary et al. (2015). Chiamsathit et al. (2016), Castillo et al. (2018)' Guven (2009)). Artificial Neural Networks which an artificial intelligence technique. This technique had overcome the limitations of the conventional methods. Many studies have been used to train and design the ANN models by applying both feed forward and back propagation methods. The model developed by using ANN gives better results as compared to the conventional methods (Sulaiman et al. (2019).

The ANN has a capacity to store entire data and can work with insufficient knowledge of the problem. It takes a large training time but evaluate the problem efficiently without error. This programme has high tolerance limit. ANN can be applied to bring improvement in the process of irrigation water management.

Fuzzy Logic (FL) Rule Based modelling

It can deal with complex problem with incomplete data and imprecise data. It can also deals with nonlinear functions. It is famous for its simplicity. Flexibility is another benefit of using fuzzy logic. It can give more accurate representation of problem (Zadeh (1965). Fuzzy optimization model can be applied for ideal operation of a multipurpose reservoir. The critical reviews of literatures suggest that comprehensive reservoir operation policy, NEFUROP (Neuro-Fuzzy Reservoir Operation Policy) was developed for full filling all the objectives for updating the rule curve. It gave effective results because fuzzy inference system deals with the uncertainty and the neural network helps in making the system adaptive and noise tolerant (Swain et al (2009)). Fuzzy enhancement demonstrate the capacity to fuse the vulnerability required in the targets and variable requests and fuzzy principles which are generally simple to clarify and get to be applied it for creating working standards for ideal operation of a reservoir. The Fuzzy logic system works in a simple manner and it is quite easy to understand. It can provide most effective solution to complex issues. It is useful in increasing the performance of the system. It also can deal the uncertainties related to Engineering problems. It has the capacity to provide effective solution to all types of complex issues. The system is very useful to modify in order to improve the performance. The system deals with various engineering uncertainties such as crop failure, water supply qualities etc.

Evolutionary Algorithm

This type of algorithms generally based on a biological evolution process to solve optimization problems. The techniques of (i) Differential Evolution (ii) Genetic algorithm are coming under this category.

Differential Evolution (DE)

Differential evolution (DE) is classified as a population-based meta-heuristic search algorithm. It applies the iterative method for getting an improved solution based on an evolutionary process. It can be applied in Irrigation engineering to develop a model for minimizing the water demand, increasing shortage and water quality. Multi-objective Differential Evolution (MoDE) also can be applied for multipurpose reservoir operation. DE is found to be more accurate and does not require any derivative. It follows the entire path to find its solution without any specified controlling parameters. It is easy & effective having lower number of iterations. It can be applied to practically to the field of irrigation management.

Genetic Algorithm

The Genetic algorithm (GA) model is very effective and efficient tool. Genetic algorithm (GA) models have been applied successfully to improve Irrigation water allocation with an objective to maximize the benefits, reservoir operation. Rainfall-runoff modeling. This is because the rate convergence is much faster with binary value coding, using modified uniform mutation, uniform cross over and tournament selection with genetic algorithm with real value coding (Sheng,

2001). Several studies conducted by Kim and Heo (2004, 2008), Raju and Kumar (2004), Kumar et al. (2006), and Simpson et al. (1994) have shown that genetic algorithms outperform traditional optimization methods, especially when the objective is to maximize irrigation release while efficiently operating a reservoir system. An integrated model, such as the multi-objective genetic algorithm (MOGA), can be developed to handle an increasing number of variables over time and consider operating costs. This approach is particularly effective for solving complex water resource problems when coupled with CDDP (Constraint Driven Dynamic Programming) (Karamouz et al., 2007; Safavi et al. (2016), Rath et al. (2018), Li et al. (2018), Minaee et al. (2019), Tyagi et al. (1984.2023), have reinforced the effectiveness of genetic algorithms in addressing complex water resource challenges. The concept of genetic algorithms is relatively straightforward, based on a local search technique to find approximate solutions rather than deterministic rules. It relies on probabilistic transition rules. Genetic algorithms have shown promise in improving outcomes in agricultural development and planning.

Swarm-Intelligence-Based Algorithms

It is another branch of Artificial Intelligence Techniques. These algorithms are based on the collective behaviour of species such as birds, insects or fishes etc. (PSO, ACO and TLBO). These techniques are mostly applied for solving the water resources problems.

Particle Swarm Optimization

This optimization can be applied for the optimal water distribution for Irrigation uses, reservoir operation, development of water supply network, hydropower generation with better output as compare to Genetic Algorithm .(Eberhart and Kennedy (1995) Shi, Y., and Eberhart, R. (1998). Chenari et al. (2016), Torkomany et al. (2021) Li et al. (2020), Babanezhad et al. (2021)). PSO requires less number of parameters and provides global optimum. It does not require any mathematical calculation of derivative and integrations. The possibility of overlapping is less in PSO. It can solve multi-dimensional and large scale problem such as Irrigation water management and crop management.

Teaching Learning Based Optimization (TLBO)

The Teaching Learning Based Optimization (TLBO) algorithm is a new efficient population based algorithm developed. It is one of the best techniques. This optimization technique is significant for its high ranking of the proposed techniques and has been proven to be most efficient when compared with other techniques. Teaching learning based with neighborhood search (NSTLBO). (Bouchekara et al. (2014), Wang et al. (2014).

Basically there are two stages of these techniques one is teaching stage and other is learning stage which has advanced over the evolutionary Techniques. The results of TLBO is better than results obtained from evolutionary Techniques. (Rao and Teja (2015), Ge et al. (2016). Kumar .V, and Yadav, S.M (2018), Ajudiya et al. (2021))

TLBO method works more accurate with lower number of Iterations. Hence this method of optimization works better in the field of irrigation management.

Ant Colony Optimization:

This Technique is useful in solving different computational problem. The results from the ACO are updated both locally and globally. It provides the solution rapidly.

ACO can be time –consuming when seeking an optimal solution. These limitations have been discussed in studies such as Dorigo et al. (1996). It is used to solve various computational problems. It finds the optimal path for the problem efficiently. The limitations of the algorithm are it theoretical analysis of the problem is difficult. The Probability distribution of the outcome changes by iteration. It is a time consuming method to get an optimal solution. (Bi et al. (2020), Yang et al. (2011).

Ant colony optimization is a one of the best tool to solve the computational problems related to different field. It works on probabilistic technique to suggest the optimal paths in different sciences and researches. Irrigation water management is a dynamic system, it depends on the various climatic factors such as rainfall, wind flow, sun duration etc. The Ant colony optimization is an effective tool to deal with management issues

related to water and land management. Optimization plays a crucial role in identifying solutions that achieve optimal outcomes, maximizing profits or outputs while simultaneously minimizing costs to the greatest extent possible. The computer based optimization techniques like Cuckoo search, Particle swarm optimization, Genetic Algorithm are applied in various cases to develop an acceptable and beneficial cropping pattern.

CONCLUSION

The release of water for irrigation can be optimized by using various optimization techniques such as LPP model, different meta-heuristic techniques such as Swarm-Intelligence-Based Algorithms (Particle swarm optimization (PSO), Ant Colony Optimization. and Cuckoo search and Algorithms Evolutionary Algorithm Genetic algorithm etc. Effect of climatic change on cropping pattern of may be carried out for a particular area. Aim of this paper is to prepare a strategic framework for assessing and optimising the irrigation water use on the water regime, especially in the command areas falling in the arid regions.

To attain the above mentioned aim, the following recommendations may be included.

a) Benchmarking can be used to assess the effectiveness of an existing distribution system in order to improve it.

b) Artificial Intelligence Techniques may be adopted for the development of beneficial, sustainable and acceptable cropping pattern with user intervention.

Irrigation water management aims to redefine and bring necessary improvement in the existing system to update operational procedures, with providing a broader outlook and paying more attention for allocation of significant variables, as per the availability of resources. This research is in line with the above; and is a right step in positive direction to use the technology for improving the system performance.

REFERENCES

1. Amini, A.(2015). Application of fuzzy multi-objective programming in optimization of crop production planning. Asian Journal of Agricultural Research. 9(5208–222.
2. Arya, C.K., Purohit, R.C., Dashora, L.K., Singh, P.K., and Kothari, M. (2017).Performance evaluation of drip irrigation systems. International Journal of Current Microbiology and Applied Sciences. 6(4), 2287–2292.
3. Alabdulkader, A. M., Amoud, Al-, Ahmed I., and Fawzi S.A, (2012). Optimization of the cropping pattern in Saudi Arabia using a mathematical programming sector model. Agricultural Economics (Czech Republic) 58, (2): 56–60.
4. Ashaary, N. A., Ishak, W. H. W., and Mahamud, R. (2015). Neural Network Application in the Change of Reservoir Water Level Stage Forecasting. Indian Journal of Science and Technology, 8(13), 1-6.
5. Ajudiya,B, Yadav, S.M, Majumdar, P.K. (2021). Optimization of cropping patterns in the command area of multiple reservoir system using TLBO algorithm. ISH Journal of Hydraulic Engineering, https://doi.org /10.1080/09715010.2021.1885507.
6. Babanezhad, M., Behroyan, I., Nakhjiri, A.T. (2021). Investigation on performance of particle swarm optimization (PSO) algorithm based fuzzy inference system (PSOFIS) in a combination of CFD modelling for prediction of fluid flow. Scientific Reports, 11,Co 505 https://doi.org/10.1038/s41598-021-81111-z.
7. Barros, M.T., Tsai, F.T., Yang, S.L., Lopes, J.E., and Yeh, W., (2003). Optimization of large-scale hydropower system operations. Journal of Water Resources Planning and Management, 129(3): 178–188
8. Baky, I. A. (2010). Solving multi-level multi-objective linear programming problems through fuzzy goal programming approach. Applied Mathematical Modelling. 34(9), 2377–2387.
9. Barlow, P. M., Ahlfeld, D. P., and Dickerman, D. C. (2003). Conjunctive-management models for sustained yield of stream-aquifer systems. Journal of Water Resources Planning and Management, 129(1), 35–48.
10. Bejranonda, W., Koch, M., and Koontanakulvong, S. (2011).Surface water and groundwater dynamic interaction models as guiding tools for optimal conjunctive water use policies in the central plain of Thailand. Environmental Earth Sciences 70:2079–2086.
11. Bouchekara, H.R.E.H., Abidob, M.A., and Boucherma, M. (2014). Optimal power flow using Teaching-Learning-Based Optimization technique. Electric Power Systems Research (114), 49–59.

12. Boustani .F and Mohammadi .H (2010) Determination of Optimal Cropping Pattern Due to Water Deficit: A Case Study in the South of Iran, American-Eurasian Journal of Agriculture and Environmental Sciences , 7 (5): 591-595.

13. Brown, P.D., Cochrane, T.A. & Krom, T.D. (2010), Optimal on-farm irrigation scheduling with a seasonal water limit using simulated annealing, Agricultural Water Management, 97 (6), 892- 900,

14. Brown P. D. (2007). Optimal Irrigation Scheduling, Ph.D thesis, University of Canterbury. Christchurch, NZ.

15. Braga, B., P.F., William Yeh, W.G., Becker, L., and Mario Barros,T.L., (1991). Stochastic optimization of multi reservoir system. Journal of Water Resources Planning and Management, 117(4), 471-481.

16. Bi, W , Xu, Y and Wang, H. (2020). Comparison of Searching Behaviour of Three Evolutionary Algorithms Applied to Water Distribution System Design Optimization. Water, 12, 695; doi:10.3390/w12030695.

17. Burt, O.R. (1964). The Economics of Conjunctive use of Ground and Surface Water. Hilgardia, 36, 31-111. https://doi.org/10.3733/hilg.v36n02p031.

18. Chow, V. T., and Windsor, J. S (1972). Multi-reservoir optimization model. ASCE (Hydraulic Div.), Vol. 98 (HY10): 1827-1845.

19. Chenari, K., Abghari, H., and Tabari, H (2016). Application of PSO algorithm in short-term optimization of reservoir operation. Environmental Monitoring and Assessment. . 188: 667(1-11).

20. Chen, C, King, C and Wang, J. (2018), Stochasti 10(2), 175,1- 13., https://doi.org/10.3390/w10020175.

21. Chang, L-C., Ho, C-C., Yeh, M-S., Yang, C-C. . (2010). An integrating approach for conjunctive-use planning of surface and subsurface water system Water Resources Management, 25:59–78.

22. Chang, L-C., Chu, H-J., Chen, Y-W. (2013). A fuzzy inference system for the conjunctive use of surface and subsurface water. Hindawi Publishing Corporation Advances i Fuzzy Systems. Article, 111,ID,,128393,http://dx.doi.org/10.1155/2013/128393

23. Chandramouli, V., and Raman, H., (2001). Multiple reservoirs modelling with dynamic programming and neural networks .J. Water Resources Management. 16, 71-88.

24. Chiamsathit, C., Adeloye A. J., and Swamy, B. S. (2016). Inflow forecasting using Artificial Neural Networks for reservoir operation. Copernicus Publications on behalf of the International Association of Hydrological Sciences. 373, 209–214.

25. Castillo,J,M Cspedes,M,S and Cuchango,E,E. (2018). Water Level Prediction Using Artificial Neural Network Model. International Journal of Applied Engineering Research, ISSN 0973-4562 13(9), 14378-14381.

26. Coulibaly, P., Anctil, F., and Bobe'e, B. (2000). Daily reservoir inflow forecasting using artificial neural networks with stopped training approach. J. Hydrology, 230 (4), 244 – 257.

27. Davidsen, C., Cardenal, S. J. P., Liu, S., Mo, X., Rosbjerg, D., & Bauer-Gottwein, P(2015). Using Stochastic Dynamic Programming to Support Water Resources Management in the Ziya River Basin, China. Journal of Water Resources Planning and Management, 141(7), [04014086]. https://doi.org/10.1061/(ASCE) WR.1943- 5452.0000482.

28. Devamane, M. G., Jothiprakash, V., and Mohan, S. (2006). Non-linear Programming Model for Multipurpose Multi-reservoir Operation. J. Hydrology, 29(3-4), 33 – 46.

29. Dorfman, R. (1962). Mathematical models: The multi-structure approach, in Design of Water Resources Systems, edited by A. Maass, Harvard University Press, Cambridge, Mass., 494-539.

30. Dorigo, M., & Gambardella, L. M. (1996). A study of some properties of Ant-Q. In H.-M. Voight, W. Ebeling, I. Rechenberg, & H.-P. Schwefel (Eds.), Proceedings of PPSN-IV, Fourth International Conference on Parallel Problem Solving from Nature, (656–665.

31. Ge, F.,Hong, L., Shi L. (2016), An autonomous teaching-learning based optimization algorithm for single objective global optimization. International Journal of Computational Intelligence Systems, 9(3). 506-524.

32. Guven, A. (2009). Linear genetic programming for time series prediction of daily flow rate. The Journal of Earth System Science, 118(2), 137 – 146.

33. Hall, W. A., and Dracup, J. A. (1970. Water Resources System, E McGraw Hill, New york,

34. Janbandhu.I, Kurian A.P and Sharma, V.(2018). International Journal of Management Studies, Vol.–V, Issue –4(2) [119-128]

35. Karamouz M, Tabari MR, Kerachian R and Zahraie B (2005). Conjunctive use of surface and groundwater resources with emphasis on water quality. In Impacts of Global Climate Change (Walton R (ed.)). ASCE, 360, 1-12, https://doi.org/10.1061/40792(173)

36. Karamouz, M., Rezapour, M. M., Kerachian, R. (2007). Application of Genetic Algorithms and Artificial Neural Networks in Conjunctive Use of Surface and Groundwater Resources, International Water Resources Association, 32(1), 163-176.

37. Kumar,V & Yadav, S. M. (2018).,Optimization of Reservoir Operation with a New Approach in Evolutionary Computation using TLBO Algorithm and Jaya Algorithm, Water Resources Management: An International Journal, Published for the European Water Resources Association (EWRA), 32(13), 4375-4391, DOI: 10.1007/s11269-018-2067-5.

38. Eberhart, R and Kennedy,J. .(1995). Particle swarm optimization. Proceedings of ICNN'95 - International Conference on Neural Networks, IEEE Service Center, Piscataway, 1942–1948.

39. Kumar, D.N., and Reddy, M.J., (2006). Ant Colony Optimization for Multi-Purpose Reservoir Operation. Water Resources Management (20): 879–898.

40. Kim, .T,J.H. Heo, D.H. Bae, and J.H. Kim. (2008). Single reservoir operating rules for a year using multi objective genetic algorithm, Journal of Hydro informatics, 10(2): 163–179.

41. Kim, T., and Heo, J. H., (2004). Multi-reservoir system optimization using Multi-objective genetic algorithms" Proceedings of the World Water and Environmental Resources Congress, 27th Jun. To 1st Jul. WERI, ASCE, Salt Lake City UT, 1–10.

42. Kumar, D. N., Baliarsingh, F., and Raju, K. S., (2010). Optimal reservoir operation for flood control using folded dynamic programming. Journal of Water Resources Management, 24(6), 1045 – 1064.

43. Kazmi, S. I., Ertsen, M. W., and Asi, M. R. (2012). The impact of conjunctive use of canal and tube well water in Lagar irrigated area, Pakistan. Physics and Chemistry of the Earth 86–98.

44. Khan, M. R, Voss C I, Yu W and Michael H A (2014). Water resources management in the Ganges Basin: a comparison of three strategies for conjunctive use of groundwater and surface water. Journal of Water Resources Management. 28, 1235–1250.

45. Li, M., Fu Q, Singh VP, Liu, D(2018). An interval multi-objective programming model for irrigation water allocation under uncertainty. J. Agricultural water management, 196: 24–36.

46. Li, K,, Xun,J, Wang, Y. (2020). Research on optimal operation of Chaohu Lake Based on the Particle Swarm Optimization algorithm, IOP Conf. Series: Materials Science and Engineering 794 012070 IOP Publishing doi:10.1088/1757-899X/794/1/012070.

47. Lalehzari, R., Nasab. B., Moazed, H., and Haghighi, A. (2015). Multi-objective management of water allocation to sustainable irrigation planning and optimal cropping pattern. Journal of Irrigation and Drainage Engineering. 142(1), 05015001-05015008

48. Muhammad, Y.S., Pflug, G.C. (2014). Stochastic vs deterministic programming in water management: the value of flexibility. Annals of Operations Research 223, 309–328 https://doi.org/10.1007/s10479-013-1455-8

49. Mansouri, R, Pudeh,H.T, Yonesi,H,A. and Haghiabi,A,H (2017). Dynamic programming model for hydraulics and water resources simulating and Optimizing water transfer system (a case study in Iran) .Journal of Water Supply: Research and Technology-Aqua, 66 (8): 684–700.https://doi.org/10.2166/aqua.2017.110.

50. Montazar, A., Riazi, H., Behbahani, S. M. (2009). Conjunctive Water use Planning in an Irrigation Command Area. Journal of the Water Resources Management) 24: 577–596.

51. Marques, G. F., Lund, J. R., and Howitt, R. E. (2010). Modelling conjunctive use operations and farm decisions with two-stage stochastic quadratic programming. Journal of Water Resources Planning and Management, Vol. 136, No. 3, (ASCE, 386–394.

52. Mohan, S., and Raipure, D. M (1992). Multi objective analysis of multi reservoir systems. Journal of the Water Resources Planning and Management, 118 (4), 356 – 370.

53. Minaeea R.P, Afsharnia,M, Alireza, M, Moghaddam, A, Ebrahimia ,A,S. Askarishahi, M, Mokhtari.M , (2019). Calibration of water quality model for distribution networks using genetic algorithm, particle swarm optimization, and hybrid methods, MethodsX, 6 ,540-548, https://doi.org/10.1016/j.mex.2019.03.008.

54. Pervez, M. S. and Hoque, M. A. (2008). Interactive Information System for Irrigation Management. Pergamon, Physics and Chemistry of the Earth, 28: 927- 934.

55. Pankaj, B.S., Naidu, M.N., Vasan, A. (2020). Self-Adaptive Cuckoo Search Algorithm for Optimal Design of Water Distribution Systems. Water Resources Management, 34, 3129–3146, https://doi.org/10.1007/s11269-020-02597-2.

56. Raman, H., and Chandramouli, V. (1996). Deriving a general operating policy for reservoirs using neural networks. Water Resources Planning and Management, 122(5), 342-347.

57. Rath, A. and Swain, P. C. (2018). Optimal allocation of agricultural land for crop Planning in Hirakud canal command area using, swarm intelligence technique., ISH Journal of Hydraulic Engineering, Taylor & Francis, 24(2), 1-13.

58. Rath, A., Biswal, S., Samantaray, S. and Swain, P.C. (2016). Derivation of Optimal Cropping pattern in part of Hirakud command area using Cuckoo Search' 'International Conference on Advanced Material Technologies(ICAMT)' IOP Publication, 1-11.

59. Rath, A, Samantaray,S, Biswal,S Swain,P,C. , (2018). Application of Genetic Algorithm to Derive an Optimal Cropping Pattern, in Part of Hirakud Command. Progress in Computing, Analytics and Networking 711-721.

60. Rao, S. V. N., Bhallamundi, S. M., Thandaveswara, B. S., Mishra, G. C. (2004). Conjunctive use of Surface and Groundwater for Coastal land Deltaic Systems, Water Resources Planning and Management. 130, No. 3, 255–267.

61. Rao, K. P., and Teja, R.B. (2015). Teaching Learning Based Optimization For Short Term Hydro-Thermal Scheduling. Conference on Power, Control, Communication and Computational Technologies for Sustainable Growth (PCCCTSG),978-1-4673-6890-2/15.

62. Raju, K.Srinivasa, and Kumar, D.Nagesh (2004). Irrigation planning using Genetic Algorithm. Water Resource Management 18: 163-176.

63. Royce, F.R, Jones J.W and Hansen J.W. (2001). Model–Based Optimization of Crop Management for Climate Forecast Applications, ASAE. American Society of Agricultural Engineers, 44:1319-1327.

64. Reddy.K, Sravanth.S, Sundaram.N (2019), International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, 8(11), 1576-1580

65. Shi Y, Eberhart R (1998). A modified particle swarm optimizer. In: Proceedings of the congress on evolutionary computation, 69–73.

66. Sulaiman,K, Hakim Ismail, L.K, Razi, M.A.M, Adnan,M.S, and Ghazali,R . (2019). Water Quality Classification Using an Artificial Neural Network (ANN).IOP Conf. Series: Materials Science and Engineering 601 012005 IOP Publishing doi:10.1088/1757-899X/601/1/012005, PP 1-6.

67. Saadat, M; Keyvan,A. ., (2017) . Reliability Improved Stochastic Dynamic Programming for Reservoir Operation Optimization, Water Resources Management 31(6), 1795-1807.

68. Rosyadi,I. (2021).Stochastic Dynamic Programming for Water Reservoir (https://www.mathworks.com/matlabcentral/fileexchange/32339-stochastic-dynamic-programming-for-water-reservoir), MATLAB Central File Exchange. Retrieved June 3,

69. Singh, A., (2014). Optimizing the Use of Land and Water Resources for Maximizing Farm Income by Mitigating the Hydrological Imbalances, Journal of Hydrologic Engineering, Vol. 19, 1447-1451.

70. Safavi, H. R., and Alijanian, M. A. (2011). Optimal crop planning and conjunctive use of surface water and groundwater resources using fuzzy dynamic programming. Journal of Irrigation and Drainage Engineering, ASCE Vol. 137, No. 6, 383–397.

71. Singandhupe, R. B., Sethi, R. R., Chakravarty, H., Mohanty, R. K., Kumar, A. (2012). Conjunctive use of surface and ground water for improving water productivity in coastal area of Orissa. India Water Week 2012 – Water, Energy and Food Security: Call for Solutions, 10-14.

72. Singh, A.; Panda, S.N.; Saxena, C.K.; Verma, C.L.; Uzokwe, V.N.E.; Krause, P.; Gupta, S.K. (2015). Optimization Modelling for Conjunctive use Planning of Surface Water and Groundwater for Irrigation. Journal of Irrigation and Drainage Engineering, 142, 0733-9437

73. Sheng-Feng Kuo, Bor-Jang Lin and Horng-Je Shieh. (2001).CROPWAT model to evaluate crop water requirements in Taiwan. 1st. Asian Regional Conference. Seoul,

74. Swain P.C. and Umamahesh V Nanduri (2009). Neuro-Fuzzy Inference System for Operation of a Multi-Purpose Reservoir', Hydro informatics in Hydrology,

Hydrogeology and Water Resources, IAHS Publication No. 331, 91-97.

75. Simpson, A. R., Dandy, G. C., and Murphy, L. J. (1994). Genetic algorithms compared to other techniques for pipe optimization. Journal of Water Resources Planning and Management, 120(4), 423–443.

76. Trezos, T., and Yeh., W. W.-G. (1987). Use of stochastic dynamic programming for reservoir management. Water Resources Research.. 23(6): 983-996.

77. Torkomany,M,R, Mohamed R., Hassan, H.S, Shoukry,A, Abdelrazek,A,M and Elkholy, M. (2021). An Enhanced Multi-Objective Particle Swarm Optimization in Water Distribution Systems Design" Water , 13(10), 334; https://doi.org/10.3390/w13101334

78. Tyagi, N. K., and Narayana, V. V. D. (1984). Water use planning for alkali soils under reclamation. Journal of Irrigation and Drainage Engineering, 110 (2), 192–207.

79. Tyagi, S, Singh,P.K, Tiwari,A.K (2023). Advancements in performance of zinc oxide/carbon quantum dots based photovoltaic tri-generation system using genetic algorithm and particle swarm optimization, Sustainable Energy Technologies and Assessments, Volume 60, 103501, ISSN 2213-1388,https://doi.org/10.1016/j.seta.2023.103501.

80. Upadhyaya, A. (2017); Computer Aided Conjunctive use of Water. Med Crave Online Journal of Civil Engineering 2(3):82-86. DOI: 10.15406/mojce.20 Reddy 7.02.00032

81. Vasconcelos, V. V., Koontanakulvong, S., Suthidhummajit, C., Martinsjr., P. P., and Hadad, R. M ((2017). Analysis of spatial–temporal patterns of water table change as a tool for conjunctive water management in the upper central plain of the chaophraya river basin, Thailand. Applied Water Science, 7: 245–262.

82. Vivekanandan N., Viswanathan K., Sanjeev Gupta. (2009). Optimization of cropping pattern using goal programming approach. Journal of operation and research, 46: 259–274.

83. Velazquez, P, Andreu, J., and Sahuquillo, A., (2006). Economic optimization of conjunctive use of surface water and groundwater at the basin scale. Journal of Water Resources Planning and Management, Vol. 132, No. 6454–467.

84. Wrachien, D. D., and Fasso, C. A. (2002), Journal of Irrigation and Drainage Engineering,. 51(1): 1-15.

85. Windsor, J. S., and Chow, V. T. (1972). Multi reservoir optimization model. Journal of the Hydraulics Division, 98(10), 1827 – 1845.

86. Wang L., Zou F., Hei X., Yang D., Chen D., and Jiang Q., , (2014). An improved teaching–learning-based optimization with neighbor-hood search for applications of ANN. Neuro -computing Elsevier (143), 231–247.

87. Xu Y-P., and Tung. Y-K. (2009). Decision rules for water resources management under uncertainty" Journal of Water Resources Planning and Management. 135:3(149), 149-159.

88. Young, G.K. (1967). Finding reservoir operation rules. Journal of the Hydraulics Division.., ASCE, 93(HY6), 297-321

89. Yang, X.-S., and Deb, S. (2010). Engineering Optimization by Cuckoo Search, Int. J. Mathematical Modelling and Numerical Optimization, 1(4), 330–343.

90. Yang, C.C,· Chang, L.C,· Chen, C.S and Yeh,M.S. (2011). Multi-objective Planning for Conjunctive use of Surface and Subsurface Water Using Genetic Algorithm and Dynamics Programming. Water Resources Management 23(3):417-437, (2007) DOI 10.1007/s11269-008-9281-5.

91. Zadeh, L. A. (1965). Fuzzy sets," Information and Control, vol. 8, no. 3, pp. 338-353.

92. Zhang,C, Yue,Q and Guo,P A (2019). Nonlinear Inexact Two-Stage Management Model for Agricultural Water Allocation under Uncertainty Based on the Heihe River Water Diversion Plan" International Journal of Environmental Research and Public Health, 16; 1-18. DOI: 10.3390/ijerph16111884

GIS based Assessment of Subsurface Water Attributes of Rasipuram Taluk in Tamil Nadu

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ABSTRACT

The GIS based assessment was conducted at Rasipuram Taluk in Tamil Nadu in groundwater for domestic and agricultural suitability, since it deemed as primary source. The Rasipuram region lies over Archaean crystallines rocks. Owing to increase in population at Rasipuram in the recent decade, consumption for both usages is disquieting. In this study, groundwater chemistry data analysed for quality studies in Rasipuram taluk and correlated to global standards. The GIS analysis results shows that exceeding value of chemical concentration for Total Dissolved Solids (174.65 Sq.Km), TH (407.94 Sq.Km), Chloride (28.87 Sq.Km),and F (2.83 Sq.Km) shows state of worsening as per global standards. Outcome of investigation showing quality converge as good for 208.09 Sq.km, moderate for 242.10 sq. km and poor for and 126.81 Sq. km respectively. It was established that astonishing rate of conductivity and chloride due to fertilizer application soaring ion concentration, revealing atrophy in diverse extent. It is inevitable to monitor quality of ground water continuously to forecast contamination so as to mitigate it by taking appropriate measures.

KEYWORDS: *GIS based assessment, Groundwater quality, Quality monitoring, Water pollution.*

INTRODUCTION

Study area

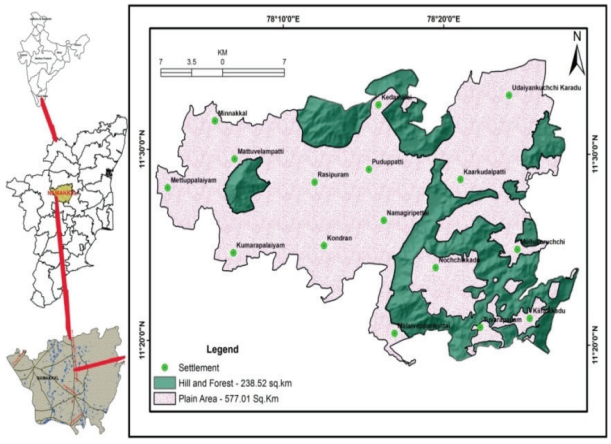

Fig. 1 Base Map of the Study Area

The study area Rasipuram is situated at Namakkal district of Tamil nadu. There are eight towns and 109 villages with in Rasipuram taluk, covering an area about 815 sq. km and having population 3,40,515 during 2011. Longitude and latitude coordinates 11° 27' 36.32" N, 78° 11' 10.86" E. This taluk is bound with 11°28′N 78°10′E / 11.47°N 78.17°E / 11.47; 78.17 ; Coordinates: 11°28′N 78°10′E / 11.47°N 78.17°E / 11.47; 78.17is shown as figure.1.

METHODOLOGY

Rasipuram taluk map with1:7,500 scale was prepared with sub surface water sample locations using geospatial technology. In this investigation sub surface water quality characteristics were analyzed. Ground water samples were collected from 45 locations of open well and bore wells.[1-3] Before collecting trial samples containers made with plastic polyethylene bottles were thoroughly cleaned and washed using sub surface water and trial samples collected. Immediately, water characteristics as pH was evaluated.[4-6] Trial

samples were sent to chemistry laboratory of Tamil Nadu Water Supply and Drainage Board (TWAD) for evaluation. Outcome the test results were articulated in milli-equivalents per litre (meq/l), parts per million and milligrams per liter (mg/l). articulated in microsiemens per centimeter and pH articulated in numbers.[8-10] Outcome of the investigation were utilized in GIS environment to make spatial distribution maps as per global standards.[11]

RESULT AND DISCUSSION

In this work, subsurface water quality parameters primarily concentrated with respect to domestic and non domestic usage. Subsurface water parameters in Rasipuram Taluk evaluated and outcome of investigation water chemistry data correlated with respect to global standards. Irrotational attribute parameters well along with as graphical illustrated as USSL diagrams, doneens classification, Wilcox diagram, etc. Investigation outcome of physico-chemical variable are illustrated in the Table 1.

Table 1. Statistical summary of chemical variable in subsurface water trials (All values in the table are articulated in ppm excluding EC in μScm^{-1} and p^H)

Variables	Minimum	Maximum	Mean	Median	Std.Dev.	Coef. Variation	Skewness	Kurtosis
pH	6.52	7.98	7.23	7.14	0.30	4.19	0.61	0.62
TDS	336.70	4063.50	1448.30	1372.7	819.59	56.59	1.39	2.59
Cl	40.04	1420.07	335.46	284.10	277.14	82.67	1.59	3.72
F	0.17	2.05	0.55	0.37	0.43	77.12	1.87	4.07
TH	123.04	1480.04	622.49	632.05	284.68	45.78	0.82	1.07

Table 2 result of Physico-chemical Parameters of groundwater as per WHO Standard

Parameters	WHO International standard (2012)		Wells surpass allowable limits	Total No. of trials	contemptible significance
	Most desirable limits	Maximum allowable limits			
pH	6.5 – 8.5	9.2	All samples within Most desirable limits	Nil	consequence of taste will be mucus membrane and in water supply system
TDS (mg/l)	507	1489	1,5,7,9,14,16,17,18,19,20,21,23,24,29,31,35,40,44.	18	Gastrointestinal Irritation
TH (mg/l)	100	500	1,4,5,6,7,9,10,14,15,16,17,18,19,20,21,23,24,27,29,32,33,34,35,37,38,42,43,44,45.	29	(i) In boilers Scale formation (ii) Cardio vascular disease
Cl^- (mg/l)	195	597	1,5,14,18,23,24,29,37,41,44.	10	Salty flavour signify pollution
F^- (mg/l)	-	1.5	All samples within Maximum allowable limits except 4th sample	1	Fluorosis

Hydrogen Ironic Concentration (pH)

One of the significant parameter of groundwater quality is pH value. Table.2 illustrates pH values in the study locale and established that it ranges between 6.52 and 7.98 and its average was 7.23 and indicates the groundwater is slightly acidic nature and dominating by alkalinity Also, it was confirmed that all the trials were within global standard prescribed values and illustrated in table 1.

Total dissolved solids (TDS)

Total dissolved solids signifies concentration of all dissolved elements in the normal charactertics of salinity of ground water. Table 2 illustrates total dissolved solids in the study locale having ranging between 336.70 to 4063.50 mg/l and mean value for 1448.32 mg/l .The maximum concentration of total dissolved solids is ascribed to appliance of farming proceedings and confer the maximum concentration of ions in to the groundwater. The three class are classified based on the WHO standard only 2.22 % samples are within most desirable limits, while 55.56 % of the wells are in between 500 and 1500 mg/l and 42.22 % of the wells are above 1500 mg/l were beyond highest allowable value as per global standard was illustrated in table 2.

The Total dissolved solids (TDS) spatial distribution map (Fig. 3) reveals that high elevated portion are represent the high concentration due to the highly weathered rock with topsoil thickness noticed during field validation. 174.65 Sq.Km area falls under undesirable limit for drinking purposes, those portions are overlaid the contact zone of rocks and fault plain so high concentration due to the high rock water interaction.

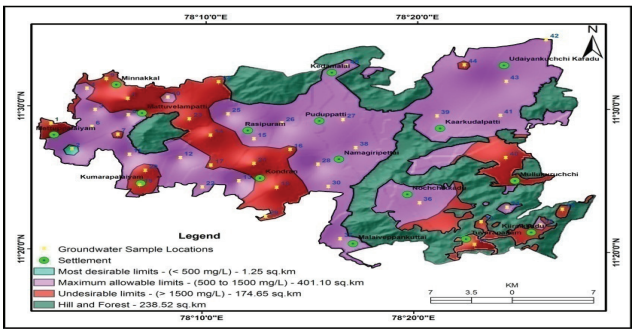

Fig. 3. TDS Spatial Distribution Map

Total Hardness (TH)

It is known that total hardness deemed as primary quality of potable water. It can express in terms of as calcium and magnesium ion elements presence with its concentration. It is matter of fact that in rocky strata and soil contains calcium (Ca) and magnesium (Mg) is in dissolved state. Owing to the existence of Calcium (Ca) and magnesium (Mg),total hardness arability in trials ranging from vary from 123.04 to 1480.04 ppm and with an mean of 622.49 ppm, was illustrated in table 1 .It is established that 64% samples were beyond optimum permissible value with respect to global standard. Outcome of the investigation shows that larger area under undesirable zone is present study area with respect to total hardness as shown in figure.4 for pre-monsoon season spatial distribution map The high elevated portion is indicating the low concentration of this parameter.

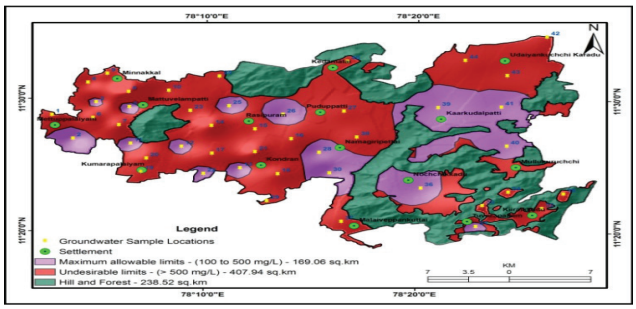

Fig. 4 Total hardness (TH) Spatial Distribution Map

Chloride (Cl)

Rocky strata and soil are sources of sodium chloride which contains dissolved chloride in water. It is excellent indication of features groundwater and its concentration in subsurface water will amplify, if it blended with sewage. Table 2 illustrate, in the study locale its value ranges in between 40.04 and 1420.07ppm and its mean was335.46ppm. It was found that 22 % trials were more than the optimum allowable value in fluvial and fissile hornblende biotite gneiss contained in black cotton soil having gypsum which may possibly be hazardous from analysis health point was illustrated in table.2 and table.3as per global standards. It could be kept that the soaring of chloride content may be ascribed to manufacturing units, domestic throw away, and discharge from upper soil stratum in dry weather and natural geochemical behavior in this locale. Outcome of

the investigations of chloride for pre-monsoon season spatial distribution map illustrated as figure.5 exhibit the standards quality of drinking usage. According to global standards it demonstrates that a tiny part fall in appalling quality for drinking usage. In all categories of rocky strata in any form chloride (Cl-) is an extensively strewn component. Chloride availability in ground water is soaring for higher temperature and minimum rainfall. Predominantly chlorides are discovered in the configuration of NaCl in the groundwater. It is established that porosity and permeability are holding primary role in chlorides presence and concentration in ground water. Presence of chlorides will cause saltines which origin the vital for the progress of crucial renal stones, osteoporosis, asthma and risk for stroke.

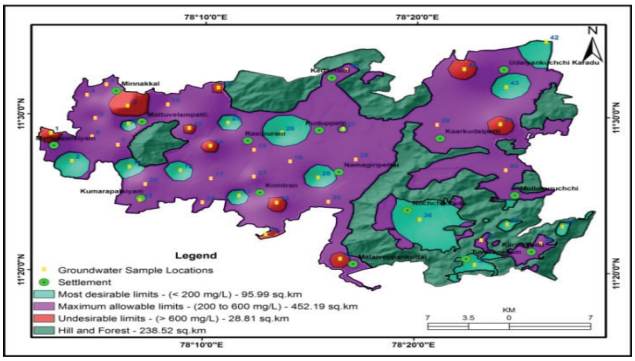

Fig. 5 Chloride (Cl-) Spatial Distribution Map

Fluoride (F)

It was established that tolerable limit of fluoride is 1.5 ppm, based on ingress of diverse sources in to subsurface water Presence of fluoride to be kept within allowable value so as to avoid diseases in dental and bone due to the formation of fluorosis. Primarily often it was unable to determine the cause of natural and geogenic contamination in subsurface and surface water. Primary sources for fluoride in subsurface water were being country rocks and fertilizers application .Fluoride consumption in excess will be cause for bone fractures in adults ill effects on bone focal reason for pain and tenderness. Most desirable limit global standard of fluoride in drinking water is 1.5 ppm. . In this investigation the concentration was higher than 1.5 mg/l in 4th location only Outcome of investigation results of fluoride spatial distribution map (Fig. 6) shows that a small patch of undesirable zone was exist in northwest corner of study locale. The high elevated portion is indicating the high concentration of this element.

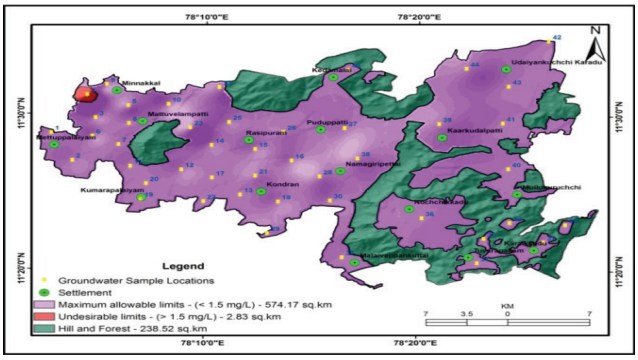

Fig. 6 Fluoride (F-) Spatial Distribution Map

Data and Maps Analysis for Drinking

Each elements of ground water quality were illustrated using thematic map such as TDS (Fig. 3), TH (Fig. 4), chloride (Fig. 5), and F (Fig. 6), and these were affords assured intimation and indications on quality features of groundwater. For sorting available data as integrated, it is critical to amalgamate these data with suitable feature. Hence, numerically this information is incorporated by using the appliance of GIS. Diverse thematic maps are categorized depending of weight age allocated, and transmitted into the "Raster Calculator" utility of spatial analysist device for amalgamation. An elemental arithmetical model has been espoused to amalgamate diverse thematic maps.Figure.7 illustrates drinking water of bad, fair and acceptable quality. This methodology it is extremely useful in evaluates the best groundwater attributes region in the study locale. It was established that bad water attributes region wrap about area 126.81 Sq. km, fair water attributes region wrap about area 242.10 sq. km and acceptable quality water attributes region wrap about area 208.09 Sq.km.

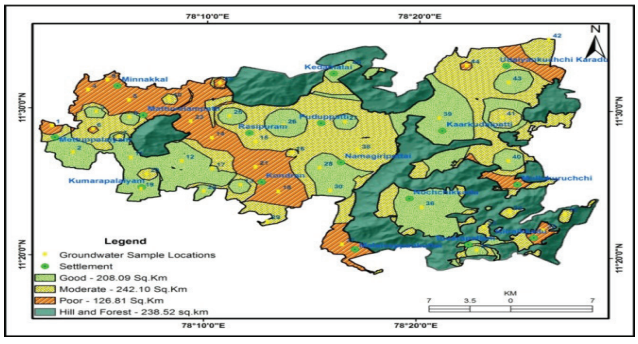

Fig. 7 Water Quality Index Map

CONCLUSION

The GIS analysis results shows that exceeding value of chemical concentration for total dissolved solids (174.65 Sq.Km), , TH (407.94 Sq.Km), Chloride (28.87 Sq.Km), SO4 (8.36 Sq.Km) and F (2.83 Sq.Km), shows signs of declination as per global standards. This methodology is extremely useful in evaluation of the best groundwater attribute region in the study locale. Outcome of the investigation established that bad water attribute region covers about area 126.81 Sq. km, while fair water attribute region covers an area of 242.10 sq. km and acceptable quality water attribute region of groundwater quality for potable rationale region about 208.09 Sq.km. The following recommendations were made from the study, this study underlines and call attention the necessity for consistent groundwater quality examining and monitoring to analyze and asses the contamination actions starting from beginning and following time to time for taking suitable management actions in point in time to mitigate the concentration of contamination action.

REFERENCES

1. Adimalla N, Manne R, Zhang Y, Xu P, Qian H. Evaluation of groundwater quality and its suitability for drinking purposes in semi-arid region of Southern India: an application of GIS. Geocarto International. 2022 Dec 13;37(25):10843-54.
2. Arivazhagan A, Senthilkumar M. Groundwater Potential Zone demarcating using GIS Technique: A Case Study in Harur Taluk, Dharmapuri District, Tamilnadu
3. Fentahun A, Mechal A, Karuppannan S. Hydrochemistry and quality appraisal of groundwater in Birr River Catchment, Central Blue Nile River Basin, using multivariate techniques and water quality indices. Environmental Monitoring and Assessment. 2023 Jun;195(6):655.
4. Gyanendra Y, Alam W. Geospatial assessment and hydrogeochemical characterization of groundwater resources of Manipur Valley, India. Environmental Monitoring and Assessment. 2023 Sep;195(9):1037.
5. Krishnaraj V, Mathesh S. Correlation of stagnant wetland depths and their ecological status in the Central Tamil Nadu District, Tamil Nadu. Environmental Science and Pollution Research. 2023 Apr;30(18):51955-76.
6. Mageshkumar P, Wani BA, Hariprasath M, Sugumaran B, Arulmozhi S. Spatial variation analysis of groundwater quality for irrigation purpose using GIS. Materials Today: Proceedings. 2023 May 16.
7. Mageshkumar P, Vennila G. Assessment of errors in water quality data using ion balancing methods-A case study from Cauvery River, South India. Indian Journal of Geo-Marine Sciences (IJMS). 2022 Oct 28;49(01):57-62
8. Mageshkumar P, Subbaiyan A, Lakshmanan E, Thirumoorthy P. Application of geospatial techniques in delineating groundwater potential zones: a case study from South India. Arabian Journal of Geosciences. 2019 Mar;12:1-5.
9. Maurya PK, Ali SA, Zaidi SK, Wasi S, Tabrez S, Malav LC, Ditthakit P, Son CT, Cabral-Pinto MM, Yadav KK. Assessment of groundwater geochemistry for drinking and irrigation suitability in Jaunpur district of Uttar Pradesh using GIS-based statistical inference. Environmental Science and Pollution Research. 2023 Mar;30(11):29407-31.
10. Saqib N, Rai PK, Kanga S, Kumar D, Đurin B, Singh SK. Assessment of Ground Water Quality of Lucknow City under GIS Framework Using Water Quality Index (WQI). Water. 2023 Aug 25;15(17):3048.
11. Tiwari, Akash, Manish Kumar, and Swati Thakur. "Groundwater Quality assessment for Drinking Purpose using Traditional and Fuzzy-GIS based Water Quality Index in Gurugram District of Haryana, India." (2023

A Study on Spin Fin Pile Under Various Loading Conditions

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ABSTRACT

The basis of an offshore wind turbine is a spin fin pile. Due to their Omnidirectional bending resistance, substantial surface area, and ease of installation, driven pipe piles are frequently utilized near offshore buildings. Spin Fin piles are standard pipe piles with flat, steel plates ("fins") attached at a slight angle across the first few feet of the pipe. These piles achieve pile capacities that are significantly higher than ordinary piles when they are driven into the earth. It has been discovered that attaching fins or wings to the surface of monopiles is an effective way to increase the lateral load and uplift load capacities of piles. Both traditional impact and vibratory hammers, along with templates and attachments, can be used to drive these piles successfully. the determination of the maximum load carrying capacity for combined, vertical, uplift, and lateral loads.

KEYWORDS: *Spin fin pile, Ultimate load capacity, Vertical load.*

INTRODUCTION

Pile supports a wide variety of towering structures, bridges, offshore projects, and transmission towers. Strong winds and seismic activity are just two of the many loads that these structures could be exposed to. It is often modified to increase pile capacity. Steel H-heaps, bladed piles, screws, modified larger ends, and steel pipe piles are a few examples. Wind turbines, both onshore and offshore, are frequently supported by monopiles. Because of the weak soil and low overburden soil pressure in the vicinity of the pile top, large diameter piles are necessary. By adding fins to the top or bottom of the monopiles, the pile capacity can be increased. This new, modified pile is known as the Spin Fin pile. Spin fin piles are frequently utilized in piling foundations for wave barriers, docks, dolphins, retaining wall tiebacks, seismic anchors, and other applications where failure due to predicted uplift or impact load is possible. This is a unique kind of pile foundation that is resistant to considerable lateral displacement and uplift. Spin finned piles are driven heaps with welded fin attachments that change the way the pile behaves under load.

The attachment of fins on to the surface of the monopiles has been found to be a good measure to improve the lateral load and uplift load capacity of piles. Spin fin piles are a cost saving alternative for many pile foundation applications. The spin fin tip generates significantly more resistance to tensile loads than that of a conventional pile.

A standard monopile with four plates welded at a 90-degree angle to one another is an illustration of a spin fin pile. It's a stack of pipes with an outside thread that progressively forms a fin around the base of the stack. For projects requiring enhanced resistance to uplift, like seismic occurrences, or for soils with less overburden

material overlaying a strong bearing layer, like glacial till over bedrock, the Spin Fin pile is especially well-suited. The fins also increase the pile section's bearing area, which increases its resistance to compression. Figure 1 depicts an example of a typical Spin Fin pile.

Fig. 1: Typical Spin Fin pile

When observed from head to tip, the top of one fin contacts the bottom of the fin next to it, as shown in Figure 2, which illustrates the fins' 360-degree coverage. Fins are easy to install after being bought or built on-site. When connected to the pile cap and serving as an anchor, the uplift capability is much enhanced compared to a pipe alone. By expanding the gross bearing area at the pile's base, the fins also increase end-bearing capacity. Because of this, the compression and tensile capacities of Spin Fin piles are usually attained at less depths than those of straight pipe piles of comparable size. This massive project is being worked on at the moment.

Fig. 2: Cross-section view of spin fin pie

Mechanism of Spin Fin Pile Capacity

The spin fin pile rotates into the earth while driving because of its fins. With help of vibratory hammers, templates, and accessories in addition to traditional impact piles are driven. These piles have substantially higher pile capacity than conventional ones because they spin into the ground when driven. After the pile is driven, it is integrated into a pile cap. When the pile is pulled in tension, it produces a dirt cone (visible in gray), which increases the pile's capacity. The lid then limits the rotation of the pile, preventing it from twisting. This may result in a plugging effect, increasing the resistance of the pile to tension loads.

Reducing both the number and the length of piles in an application can result in significant cost savings for the building industry. Construction time is shortened by the need to drive fewer, shorter piles and by using smaller cranes and equipment. A spin fin pile costs less than a conventional pile. Figure 3 circular pile and spin fin pile comparison.

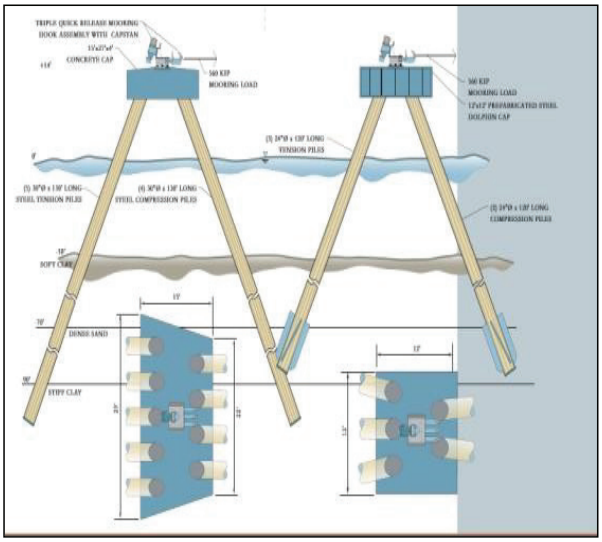


Fig. 3: Comparison between the structure with the Spin Fin pile and that of a conventional pile

The Spin Fin pile rotates into the earth while being driven by its fins. These piles can be driven successfully using templates and attachments, as well as conventional impact and vibratory hammers. These piles have a far higher pile capacity than conventional ones and rotate into the ground when pushed. After being driven, the pile is then included in a pile cap. Figure 4 illustrates a Spin Fin pile in tension and compression.

When the pile is pressed in tension, a dirt cone (which is visible in grey) is created, increasing the pile's capacity. The lid then limits the rotation of the pile to stop it from

twisting, which increases the pile's resistance to tension loads..

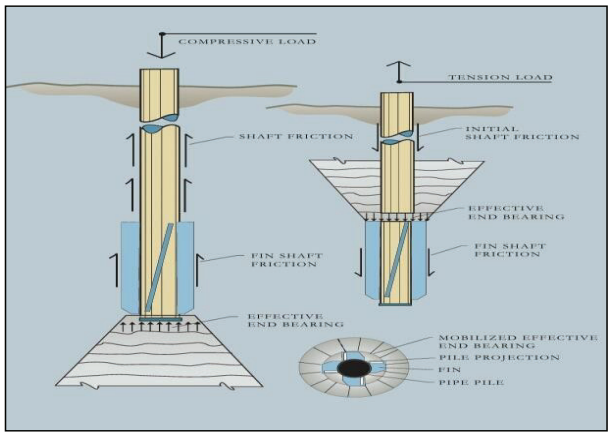


Fig. 4: Spin Fin pile load transfer mechanism

Advantages of Spin Fin pile

Following are some advantages of spin fin piles.

- In soft soil, Spin Fin piles require 50% less length than conventional piles.
- Uplift forces are produced by the rocking action of wind and earthquakes. When water levels rise beneath an ice sheet that is clinging to a building or pile, ice uplift takes place. One way to prevent uplift is to utilize spin fin piles.
- Under cyclic loading, the spin fin pile shows notable reserve strength. • This pile can take a significant amount of energy through deflection without losing strength, especially in breasting dolphin structures. This has advantages in seismic situations.
- Even after repeated loading, the deformation characteristics of Spin Fin piles permit significant pile overload deformation without catastrophic failure.
- Tests have been conducted on pile tensile capacities exceeding 800 kips with a pile embedment as short as 50 feet.
- There are major financial implications when the quantity and length of heaps are reduced.

Applications

- Many transmission towers, high-rise buildings, and bridges are supported by piles.
- Near and offshore structures such as dolphins, piers, moorings, and wind turbines are subject to severe and cyclic loading conditions

Loading Conditions of Spin Fin Pile

Spin sin pile foundation is used in offshore as well as onshore foundations.

Lateral Loading - However, offshore structure foundations must withstand substantial environmental stresses from wind, waves, and currents, which can result in lateral loads equal to or greater than one-third of the vertical loads. Structures subject to wind-earthquake loads, retaining walls, bridge abutments, and other pile foundation supporting structures may be affected by lateral loads. A recently invented kind of pile foundation that can withstand heavy lateral loads is a pile with fins.

Vertical Loading – Large vertical loads from the superstructure are typically transmitted into the underlying bearing strata via weaker subsoil using onshore piles. Since the lateral loads operating on pile foundations are sometimes much smaller than the vertical loads, they tend to be ignored.

Uplift Loading - The tensile capacity of a spin fin pile relies on both skin friction and the uplift bearing capacity of the fins, much like helical anchors. There is a strong correlation between the skin friction along the pile and the uplift bearing from the fins, therefore, if accurate skin frictional information is known, the ultimate capacity of the pile is more precisely determined. The fins also increase the gross bearing area at the bottom of the pile and improve the end bearing capacity. As a result, the compression and tensile capacity for Spin Fin piles is usually achieved at shallow depths compared to similarly sized straight pipe piles.

LITERATURE REVIEW

K.V. Babu et al. (2018) conducted an analysis of fin piles' lateral load response. The lateral load response of fin piles in sand and normal piles—piles without fins—was studied using numerical models. Fin piles and standard heaps were subjected to three-dimensional finite element analyses. In sand with varying relative densities—40%,55%, and 85%—analyses were conducted. During the analyses, regular and fin piles

with four and eight fins were taken into account. In sand, the behavior of fin heaps and regular piles with various fin orientations, numbers, and positions in relation to the sand were studied. They came to the conclusion that star fin piles, as opposed to straight and diagonal fin piles, carried a greater lateral load at higher fin lengths. Fins placed near the pile top provided more resistance than those placed near the pile bottom.

J. R. Peng et al. (2010) performed study on fin piles loaded laterally. To investigate the impact of fin diameters on their load bearing capability in sand, a three-dimensional (3D) computer simulation of laterally loaded fin piles was given. Using PLAXIS-3D software, the behavior of fin piles and the monopile was examined in order to produce pile head P-Y curves. They came to the conclusion that as fin length rose, so did lateral resistance. When the fin length is half the pile length, a fin pile has its maximum fin efficiency. Fins toward the top of the pile offered greater resistance than fins near the bottom of the pile.

S. W. Thakare et al. (2019) experimental research on rectangular spin fin piles for various loading modes. In the experimental examination, fins in the middle, bottom, and top of the spin fin pile were all taken into consideration. The results showed that spin fin piles with fins at the bottom provide substantially higher strength than traditional circular piles in both vertical and uplift capacities. Compared to conventional circular piles, spin fin piles with fins at the top have a larger lateral load capability.

N.G. Tale et al. (2019) performed a numerical analysis for a spin fin pile under various loading situations using MIDAS GTS 3D software. Studies were conducted by varying the fin placements, loading conditions, and relative densities. According to analysis, spin fin piles with fins at the bottom have a higher vertical capacity than ordinary piles.

P. Bariker et. al. (2020) carried out an experimental study to find lateral strength of a triangular fin pile's in sand. During the studies, there were variations in the relative density, pile length, number of wings, fin orientation, fin diameter, and pile type. It was determined that fin heaps offer significantly more lateral resistance than a standard circular pile. More resistance is provided by the fins at the pile head than by the pile bottom.

W. R. Azzam et al. (2017) conducted an experimental investigation of the behavior of single-finned piles under tension loads in sand. Comparative small-scale model uplift experiments were conducted on both fin-equipped and non-finned normal piles. The fin-width ratio (b/D), fin inclination angle (β), pile length-to-diameter ratio (L/D), and soil density were varied during the investigations. It was determined that in order to have the greatest positive impact, the ideal inclination angle of fins should be between (β) equal to and more than 45°. The modification of sand relative density from 50% to 85% increased the ultimate uplift load by 120% and 56% for pile L/Ds of 15 and 30, respectively, for finned piles with (b/D = 1, β = 90°).

Mohamed A. Sakr et al. (2019) conducted a study for uplift loading conditions on a single pile in sand that had wings shaped like triangles. The improved pile–soil interaction was modeled using a nonlinear 3D analysis that included interface elements, an elastic plastic soil model, and an elastic pile material. A finite element analysis PLAXIS 3D numerical research was conducted on piles with and without wings. Research was conducted by varying the number of wings (nw = 0, 2, and 4) and the wing-width ratio (Dw/dp = 2, 3, 4 and 5). We also took into account the effects of relative sand densities. The adopted wings at the pile end significantly increase the uplift capability with minimal distortion, according to the results. It has been observed that the wing efficiency for uplift capacity improves as the relative densities of sand increase, for a certain wing-width ratio (Dw/dp). For sand densities of 30%, 50%, and 80%, respectively, the improvement in the uplift capacity is determined to be (2.2, 2.33, and 2.45) times that of a conventional pile without wings for the wing-width ratio (Dw/dp of = 5) and number of wings (nw = 4). Because the soils within the wings have a considerable locking-up effect that results in higher uplift capacity, the presence of such wings at the bottom half of the piles provided an appropriate anchorage system.

Ahmed M. A. Nasr et al. (2013) conducted an experimental study using finned piles that were laterally loaded in sand. In their investigation, they assessed how a pile with fins positioned near to the pile head improved lateral capacity. Regular piles with

and without fins were subjected to model tests and numerical analysis. The sand in which the piles were placed had varying relative densities (Dr = 35% and 78%). The length, width, form, and type of pile were changed in order to conduct the testing and analysis. A comparative analysis was conducted between the model results and the prototype-scale results. When compared to a standard reference pile, they found that heaps with fins offered significantly higher ultimate lateral loads and lateral resistance.

The length of the fins had a major influence on the ultimate lateral load improvement, which increased noticeably when the length of the fin to length of pile ratio (LF/LP) reached 0.4. The ultimate lateral load of a pile enhanced by approximately 64% and 86%, respectively, when finned with triangular and rectangular fins compared to a conventional pile. Concurrently, there was a roughly 37% and 70% decrease in the lateral head deflection, respectively. Therefore, piles with rectangular fins performed better in terms of enhancing pile lateral behavior.

Shubhravi M. Akotkar, et al. (2020) A trapezoidal spin fin pile that was subjected to vertical loading was the topic of numerical study. Trapezoidal spin fin The many characteristics of the sandy soil beneath the pile foundation were investigated. Using a number of recommended parameters, an analytical model for a spin fin pile will be built in the MIDAS GTS NX 3D software to simulate the pile foundation. They came to the conclusion that a standard circular pile's vertical load-carrying capability can be doubled by adding an inclined trapezoidal spin fin pile.

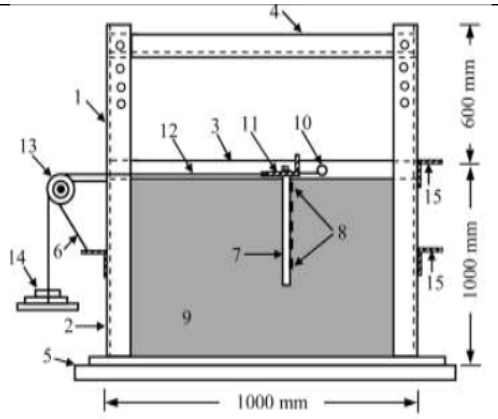
P. P. Gawande, et al. (2020) A trapezoidal spin fin pile under uplift loading was the focus of a numerical investigation. The effectiveness of the trapezoidal spin fin under investigation pile foundation located in sandy soil with respect to its various characteristics. To accomplish this, an analytical model of a spin fin pile will be made utilizing a number of recommended parameters in the MIDAS GTS NX 3D software to simulate the pile foundation. They concluded that the uplift load-carrying capability of a standard circular pile is increased with the addition of a trapezoidal spin fin pile.

BEHAVIOR OF SPIN FIN PILE

Laboratory Studies

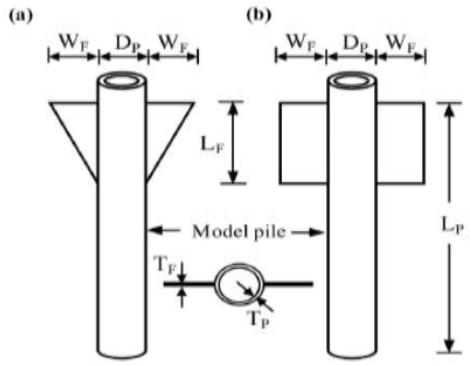
A number of researchers have been utilizing small-scale laboratory testing facilities to investigate the behavior of spin fin pile under lateral loading. In 2014, Ahmed M.A. Nasr conducted research using model test studies to examine the behavior of finned piles under lateral loads in sand deposits with varying densities. The fins' length, width, form, and kind of pile were all changed during the experiments. The results show that after installing the fins near to the pile head, the piles' lateral resistance significantly increases. Up until the fin's length equals 0.4 of the pile length, the lateral resistance increases as the fins' length grows.

Ahmed M. A. Nasr4 et al. (2013) conducted an experimental study using finned piles that were laterally loaded in sand. They attempted to assess the improvement in lateral capacity of a pile with fins installed near the pile head in their study. Regular piles without (fins) and piles with fins were the subject of small-scale model experiments and a computer investigation utilizing finite element analysis. The sand in which those piles were placed had varying relative densities (Dr= 35% and 78%). The fins' length, width, form, and kind of pile were all changed during the experiments. Additionally, a comparison between the prototype-scale results and the model results was examined. Figure 5 displays a schematic elevation view of the test configuration.



1- Loading frame; 2- Test tank; 3- Thick glass wall; 4- raining device; 5- Steel base; 6- Stiffener plate; 7- Model pile; 8- Strain gauges; 9- Sandy soil; 10- Dial gauges; 11- Model pile cap; 12- Steel wire; 13- Smooth adjust Pulley; 14- Weights; 15- Stiffener angles;

Fig. 5: Schematic Elevation View of Test Configuration (Ahmed M. A. Nasr, 2013)



D_P = pile diameter (constant); L_P = embedded length of pile; W_F = fin width; L_F = fin length; T_P = thickness of pile wall; T_F = thickness of fin wall (constant).

Fig. 6: Different Shapes of Fins

Two distinct fin forms that were employed in the trials are depicted in Figure 6. Using steel sheets that were 2.0 mm thick, fins of two different diameters were formed into triangles and rectangles. When compared to a standard reference pile, fin-equipped piles yielded significantly greater ultimate lateral loads and lateral resistance behavior. The fins' length had a considerable impact on the ultimate lateral load improvement, which rose to a value of LF/LP = 0.4. Additional fin length increases did not have a significant impact on the pile capacity. As the fins' length increased, the lateral head deflection reduced. The fin efficiency rose as fin width grew for both short and long pilesThe ultimate lateral load of a pile enhanced by approximately 64% and 86%, respectively, when finned with triangular and rectangular fins compared to a conventional pile. Therefore, it was more successful to use rectangular fins to improve the lateral behavior of piles. Fins can be used to gain lateral resistance while reducing the length of a finned pile in comparison to a standard pile.

S. W. Thakare et al. (2019) studied performance of spin fin pile under different loading modes. The static lateral pile load test were conducted on a model pile foundation as per IS: 2911- (part 4) 1985 to evaluate the lateral pile capacity. The lateral load to the piles was applied through static loading with help of a pulley and string system as shown in Figure 7.

Fins at the bottom, middle, and top of the spin fin pile were the three placements of fins that were taken into consideration in the experimental inquiry. The ultimate capacity of the piles are contrasted with the same diameter and length of a traditional circular pile. Figure 8 displays the load vs. settlement curves for a spin fin pile with a different fin position and a regular circular pile subjected to lateral load.

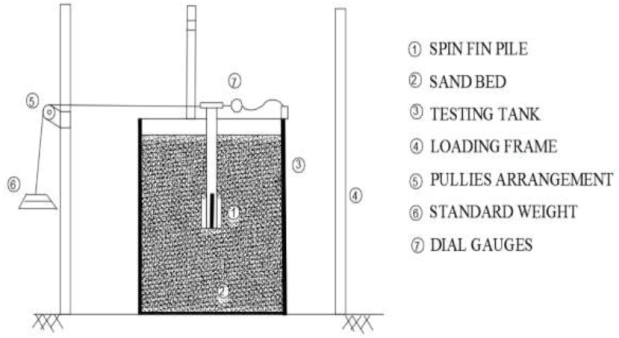


Fig. 7: The Schematic Diagram of the Test Setup for Lateral Loading used for Experimental Investigations

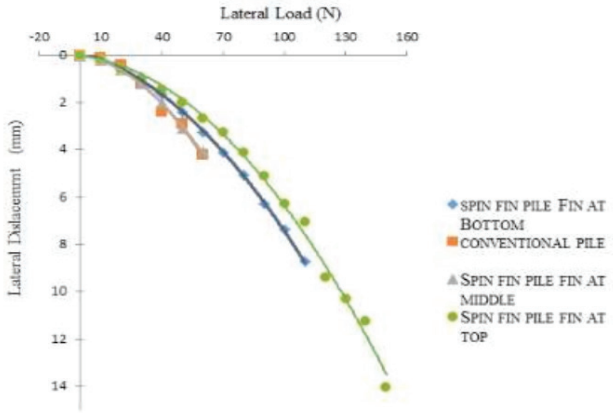


Fig. 8: Lateral load vs. lateral displacement curves for conventional circular pile and spin fin pile with different fins position.

It is observed that lateral load capacity of Spin Fin Pile with fins at top is maximum as compared to Spin Fin Pile with fins at middle and bottom and that of conventional circular pile.

Analytical Studies

K.V. Babu1 et al. (2018) conducted an analysis of fin piles' lateral load response. The lateral load response of fin piles in sand and normal piles—piles without fins—was studied using numerical models. Fin piles and standard heaps were subjected to three-dimensional finite element analyses. In sand with varying relative densities—40%,55%, and 85%—analyses were conducted. During the analyses, regular and fin piles

with four and eight fins were taken into account. The impact of fins' orientation and placement on the lateral load response of fin piles was emphasized, together with the relative density of the sand. Figure 9 show the normalized lateral load carrying capacity of regular and fin pile with various density indices having different fin orientations.

Fin direction, fin position, and relative density of the sand all affect the increase in lateral load. The total pile length and diameter were decreased with the aid of these characteristics. When compared to ordinary piles, fin piles in loose sand demonstrated a lateral load carrying capability improvement of about 60%. The lateral load carrying capacity of fin piles in medium dense sand was found to be around 65% higher than that of ordinary piles. When compared to ordinary piles, fin piles in dense sand showed an improvement in lateral load-carrying capacity of about 75%. Star fin piles, followed by straight and diagonal fin piles, carried a greater lateral strain at longer fin lengths. More resistance was offered by fins positioned close to the top of the pile than by those toward the bottom.

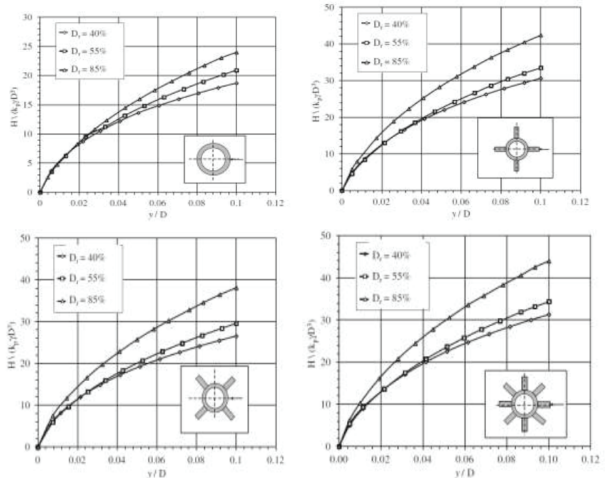


Fig. 9: Normalized lateral load-deflection curves for regular and fin piles, (a) regular pile, (b) straight fin piles, (c) diagonal fin piles, (d) star fin piles (K.V. Babu et al.,2018)

CONCLUSION

1. Spin fin piles with fins at the bottom have a far higher ultimate vertical load capacity and uplift capacity than spin fin piles with fins at the middle and top.
2. The lateral load capacity of spin fin piles with fins at the top is much higher than that of spin fin piles with fins at the bottom and center.
3. The highest vertical capacity The capacity of spin fin piles in dense sand are higher than those in loose sand.
4. The maximum vertical load capacities for both types of piles increase with pile count.

REFERENCES

1. Ahmed M.A. Nasr (2014), "Experimental and theoretical studies of laterally loaded finned piles in sand", Can. Geotech. J. 51: 381–393.
2. Azzam W. R. and Elwakilb A. Z. (2017), "Model Study on the Performance of Single Finned Pile in Sand under Tension Loads", International Journal of Geomechanics, © ASCE, ISSN 1532-3641.
3. Babu K. V., and Viswanadham B. V. S. (2018), "Numerical Investigations on Lateral Load Response of Fin Piles", Numerical Analysis of Nonlinear Coupled Problems, Sustainable Civil Infrastructures, DOI 10.1007/978-3-319-61905-7_27.
4. K. Madhusudan Reddy and R. Ayothiraman, "Experimental Studies on Behavior of Single Pile under Combined Uplift and Lateral Loading", Journal of Geotechnical and Geoenvironmental Engineering, © ASCE, ISSN 1090-0241/04015030(10).
5. Jan Duhrkop and Jurgen Grabe, (2008) "Laterally Loaded Piles With Bulge", Journal of Offshore Mechanics and Arctic Engineering NOVEMBER 2008, Vol. 130 / 041602-1 13.
6. Britta Bienen, Jan Duhrkop, Jurgen Grabe, Mark F. Randolph and David J. White (2012) "Response of Piles with Wings to Monotonicand Cyclic Lateral Loading in Sand",364 / Journal of Geotechnical and Geoenvironmental Engineering © ASCE / March 2012
7. Mohamed A. Sakr, Ashraf K. Nazir, Waseim R. Azzam and Ahmed F. Sallam, (2019) "Uplift Capacity of Single Pile with Wing in Sand-Numerical Study", International Conference on Advances in Structural and Geotechnical Engineering, ICASGE'19, 25-28 March 2019, Hurghada, Egypt.
8. J. R. Peng, M. Rouainia, and B. G. Clarke (2010), "Finite element analysis of laterally loaded fin piles", Computers and Structures 88 (2010) 1239–1247.

9. P. P. Gawande and Dr. A. I. Dhatrak (2020) "Numerical Analysis on Trapezoidal Spin Fin Pile Subjected to Uplift Loading" International Journal for Research in Applied Science & Engineering Technology (IJRASET) ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429 Volume 8 Issue XII Dec 2020

10. Rekha Ambi, Jayashree P. K. and UnnikrishnanN (2017) "Effect of Fin Length on the Behaviour of Piles under Combined Loading Conditions", Indian Geotechnical Conference (2017).

11. Shubhravi M. Akotkar and Dr. A. I. Dhatrak (2020) "Numerical Analysis on Trapezoidal Spin Fin Pile Subjected To Vertical Loading" International Research Journal of Engineering and Technology (IRJET), Volume: 07 Issue: 12 / Dec 2020.

12. Steven Halcomb, Sean Sjostedt, and Charles Somerville (2018). "High Strain Dynamic Testing of Spin Fin Piles", IFCEE2018 GPP 11©ASCE.

13. N.G. Tale, Dr. A. I. Dhatrak and S. W. Thakare (2019), "Numerical analysis of spin fin pile under different loading conditions", International Journal of Technical Innovation in Modern Engineering & Science, e-ISSN: 2455- 2585 Volume 5, Issue 05.

14. S. W. Thakare, P. P. Wankhade and Dr. A. I. Dhatrak (2019) "Experimental investigations on performance of spin fin pile under different loading modes", International Journal of Technical Innovation in Modern Engineering & Science, e-ISSN: 2455-2585.

Numerical Studies on Behavior of Strip Footing on Stabilized and Unstabilized Soil Slope under Different Soil Foundations

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ABSTRACT

Due to rising urbanization, unlimited land has become finite; making the availability of land for infrastructure projects a critical challenge. Foundations are frequently erected along slopes in a variety of civil engineering applications, including commercial structures, road infrastructure and bridge supports. But still, the stability and endurance of such structures at the slope edge is a difficult problem. The current work uses the finite element program MIDAS GTS NX to determine the strip footing's bearing capacity on stabilized and unstabilized soil slopes under varied soil foundations with steep soil slopes. Commercial residue, such as fly ash, is utilized to stabilize soil slope. The optimal dose of fly ash is determined based on laboratory data. Various soil models are prepared and analyzed in software to assess the influence of varied edge distances and soil foundations on the load carrying capacity of strip footings, and the outcomes are displayed using MIDAS GTS NX for stabilized and unstabilized situations. The test findings indicate that strip footing's carrying capability improves significantly with varied crest distance and for the stiff foundation conditions.

KEYWORDS: *Fly-ash, Stabilized, MIDAS-3D, Earthen slope, Embankment.*

INTRODUCTION

In a variety of civil engineering applications, foundations are frequently erected close to slopes, including structures, transmission towers, roadway pavement embankments, and bridge abutments. However, stability and long term performance of such structures near to slope facia is a difficult challenge to solve because both the long term performance and load carrying capabilities of such footings and embankments must be considered. Thus, for a long time, the idea of strengthening the earthen slope has been a primary area of study for researchers. Typical examples include applying chemical grouting, modifying the slope's surface, and employing geosynthetic layers as a kind of reinforcement, etc. The present investigation focuses on the use of waste products such as fly-ash as a stabilizing component for clay soil on various soil foundations. To improve natural soil's capacity to support more weight, fly ash is utilized as a stabilizing agent in the slope. The laboratory data is utilized to estimate the optimal fly ash dose for usage in the slope. The prototype soil model is tested for plane-strain conditions using MIDAS GTS NX, with the Non-linear Static method being employed for analysis. To provide good precision in the findings, the mesh is produced both for the soil model and the footing. Finer meshing is chosen to obtain accurate analytical results. Soil slope is built on three different soil foundations such as fly ash, clay, and sand. Analysis is performed for two distinct cases: unstabilized slope

and stabilized slope. When it comes to an unstabilized soil slope, entire slope geometry is assigned with the properties of Black cotton soil derived from laboratory testing, and in the other instance, stabilized soil properties are applied to analyze the required case. Several prototype models were examined to determine the impact of varying crest distances on load carrying capabilities. To acquire the best loading capacity value in each prototype model test, the other parameters were held constant while one parameter was changed. The spaces that exist between the slope's edge and the footing, as well as diverse soil foundations are among the several conditions investigated for load carrying capacity. Although many research projects have been conducted to investigate the behavior of slopes stabilized with different layers of geogrids as reinforcement, relatively little is known about stabilized soil slope instances.

The main objective of this study is to investigate a variety of important issues, including the effect of fly ash as a stabilizer on the bearing carrying capacity of footings, additionally the effect of various soils used in the foundation, and to recommend appropriate edge distance and type of foundation.

MATERIAL PROPERTIES

In the current investigation, the soil model is modeled using Mohr-Coulomb method and steel footing was modelled as an elastic material. Laboratory tests provide the parameters required for each analysis to establish the soil slope model, i.e., for stabilized and unstabilized soil. These are the dry unit weight (γ-dry), poisson's ratio (μ), cohesion (c), internal friction angle (ϕ), and modulus of elasticity (E).

Earthen Soil

The available literature data from Dhatrak and Langote (2024) [5] provided the properties of the clayey soil used in the prototype model test. Properties of soil are given in table no 1.

Table 1. Soft Clay Properties (Earthen Soil)

Liquid limit	47 %
Plastic limit	35.14 %
Shrinkage limit	11.18 %
Optimum water content	24 %
Dry unit weight	14.12 kN/m^3
Cohesion	46 kN/m^2
Internal friction angle	8^o

Fly Ash

Fly ash is the by-product obtained by burning of pulverised coal in thermal power plant. The parameters of fly ash used in this study are taken from the literature that is currently accessible of Langote and Dhatrak (2022) [5] which were procured from Ratan India Power Ltd. Nandgaon Peth MIDC, Amravati, and Maharashtra. India. Fly ash contains 68% silt and 28 % sand, as per the particle size distribution. The properties of fly-ash are given in table 2.

Table 2. Fly-ash Properties

Optimum water content	21.9 %
Dry unit weight	15.3 kN/m^3
Cohesion	22 kN/m^2
Internal friction angle	11^o

Stabilized Soil

Fly ash was used as a stabilizing material in the testing program. Series of unconfined compression strength test were carried out to find optimum percentage of fly ash in soil. After performing the test optimum content was observed to be at 25%. Table 3 shows the properties of Fly ash stabilized soil.

Table 3. Stabilized Soil Properties

Optimum water content	21.9 %
Dry unit weight	15.3 kN/m^3
Cohesion	22 kN/m^2
Internal friction angle	11^o

PROTOTYPE STUDY AND METHODOLOGY

The analytical work is carried out using MIDAS - 3D software for the unstabilized and stabilized soil slopes, and the load carrying capacity is analyzed using data received from laboratory test results. Figure 1a shows the 3D mesh generated model and 1b shows the failure of deformed slope model.

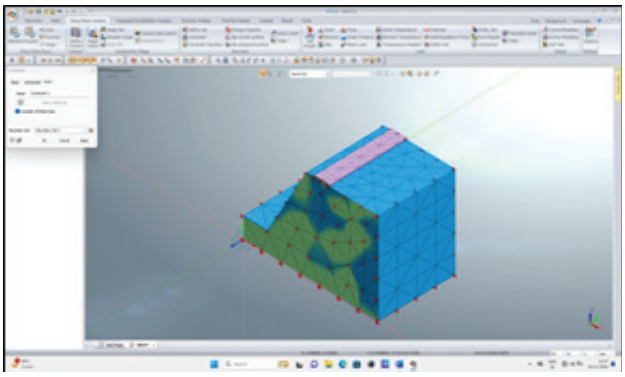

Fig. 1(a): Generated Mesh

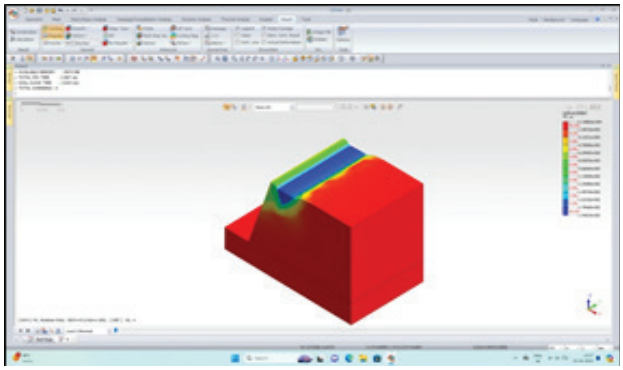

Fig. 1(b): Failure of Footing

Fig. 1: Slope Geometry in MIDAS GTS NX

Finite Element Method

The current work aims to comprehend the load carrying capacity behavior of strip footing placed on unstabilized and stabilized soil slope by performing a series of tests using three-dimensional finite element analysis (FEA) on a prototype footing slope model using the MIDAS program. Figure 2 displays the slope geometry prototype.

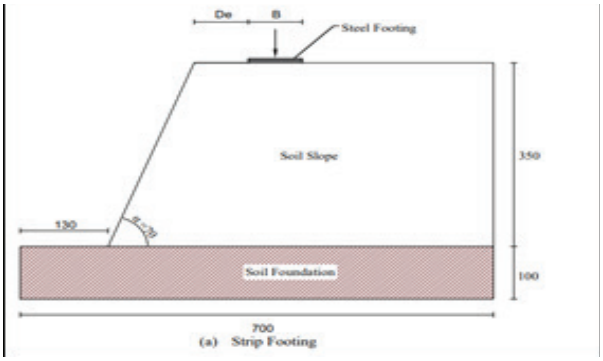

Fig. 2: Slope Model Used in MIDAS GTS NX

A yielding base was expected to support the prototype soil model. Width and depth of soil foundation are taken as 700 mm and 100 mm respectively. Soil slope is assumed to resting on soil foundation with a steep slope angle of 70o. Height of slope is 350 mm. Soil slope is analysed for varying parameters mention in table 5. In first case unstabilized soil slope is prepared over different soil beds and tested for strip footing to determine the load carrying capacity. In the second case soil is mixed with optimum dose of fly ash to prepare stabilized soil slope. Mohr-Coulomb and plane-strain analyses can be carried out by the software.

Table 4 Standards used for the Finite Element Method (MIDAS GTS NX)

Parameter	Clayey Soil	Stabilized Soil	Footing
Cohesion (C-kN/m^2)	24	22	-
Friction angle (ϕ)^o	5	11	-
Dry Unit Weight (γ-KN/m^3)	14.12	15.3	-
Poisson's ratio (μ)	0.42	0.4	0.28
Modulus of Elasticity (E-KN/m^2)	5000	9000	21x10^7
Angle of Dilatancy (ψ)	-	-	-

Table 5 Parameters used into the software model for evaluation

Test Series	Constant Parameters	Varied Parameters
	Unstabilized Soil Slope	
1.	Strip footing	De/B = 0.5, 1, 1.5,2,2.5,3,3.5,4
	Slope angle	$\alpha = 70^0$
	Slope Foundation	Fly ash, Clay and Sand
	Stabilized Soil Slope	
2.	Slope angle	$\alpha = 70^0$
	Strip footing	De/B = 0.5, 1, 1.5,2,2.5,3,3.5,4
	Slope Foundation	Fly ash, Clay and Sand

RESULTS AND DISCUSSION

The prepared slope model was analyzed to determine the ultimate bearing capacity of strip footing for various crests to width ratios corresponding to different soil foundations. Following section shows the pressure vs. settlement graphs for different conditions, the ultimate bearing capacity can be obtained by drawing tangent to the curve. Figure 3 shows pressure settlement curve for unstabilized slope for Fly ash foundation.

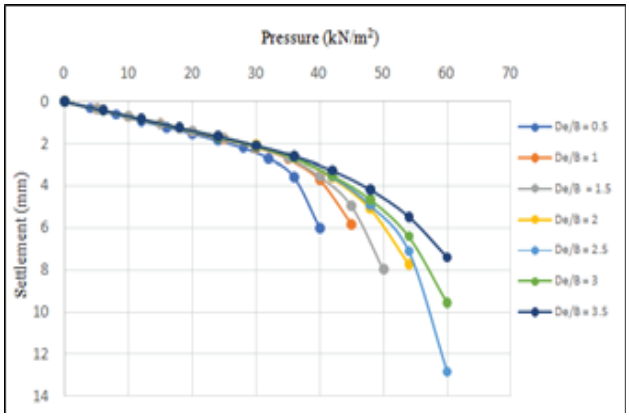

Fig. 3: Pressure against Settlement curve for Unstabilized Soil Slope for Fly ash Foundation

Figure 4 shows pressure settlement curve for unstabilized slope with clay foundation for different crest to width ratio.

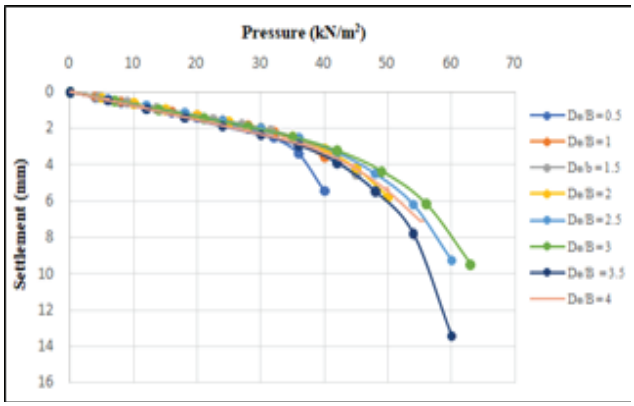

Fig. 4: Pressure against Settlement curve for Unstabilized Soil Slope for Clay Foundation

Figure 5 shows pressure settlement curve for unstabilized slope with Sand foundation for different crest to width ratio.

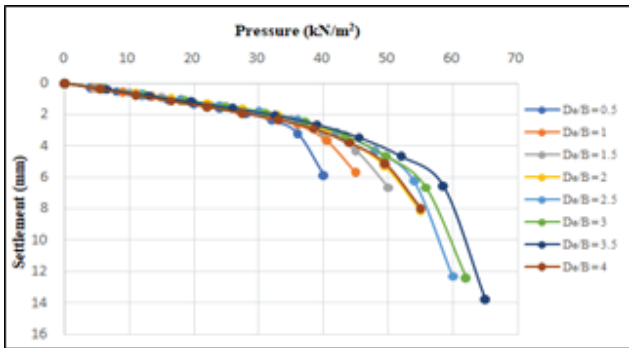

Fig. 5: Pressure against Settlement curve for Unstabilized Soil Slope for Sand Foundation

Figure 6 shows pressure settlement curve for stabilized slope with Fly ash foundation for different crest to width ratio.

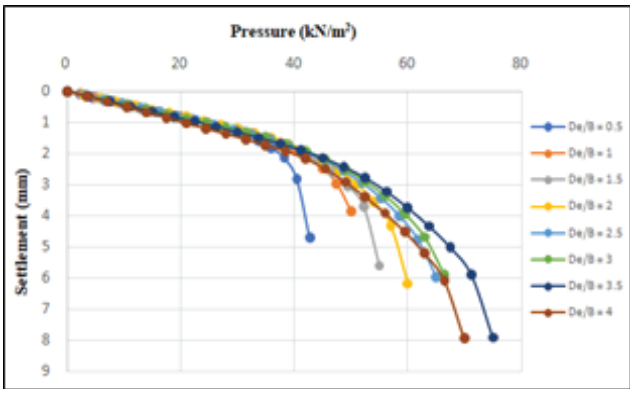

Fig. 6: Pressure Settlement curve for Stabilized Soil Slope for Fly ash Foundation

Figure 7 shows pressure settlement curve for stabilized slope with clay foundation for different crest to width ratio.

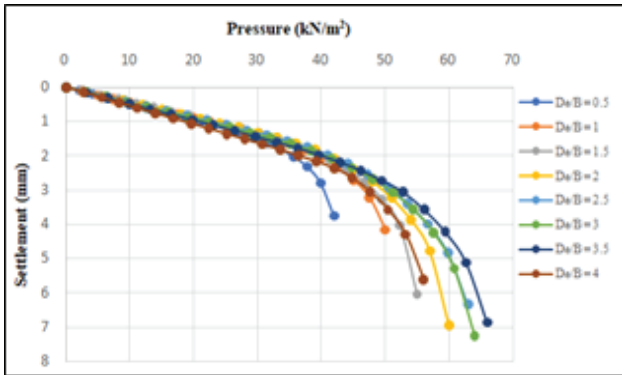

Fig. 7: Pressure Settlement curve for Stabilized Soil Slope for Clay Foundation

Figure 8 shows pressure settlement curve for stabilized slope with sand foundation for different crest to width ratio.

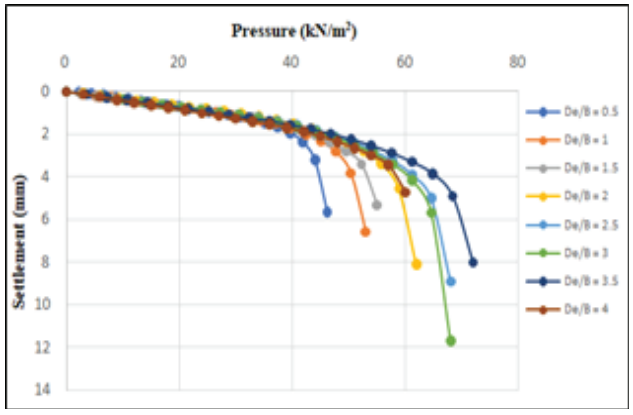

Fig 8: Pressure Settlement curve for Stabilized Soil Slope for Sand Foundation

Effect of De/B Ratio

Crest to width distance is proven to be an important parameter as far as the performance of footing is concerned. In the present study it is evident that as De/B ratio increases, the maximum bearing capacity for different soil foundations increases upto certain limit thereafter it decreases. For unstabilized slope, the behaviour of bearing capacity of strip footing with respect to De/B ratio for various foundations is shown in figure 9.

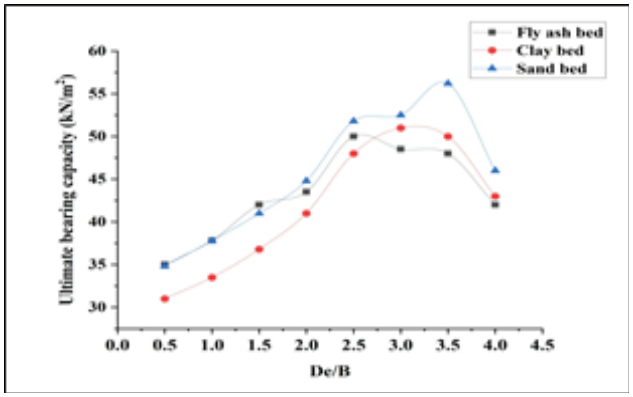

Fig 9: Ultimate Bearing Capacity Vs De/B Ratio for Different Soil Foundations for Unstabilized Slope

Figure 9 illustrates that the maximum ultimate bearing capacity is achieved with a sand soil foundation with a de/B ratio of 3.5 further the bearing capacity falls as the crest to width ratio increases.

For stabilized soil slope, the behaviour of ultimate bearing capacity of strip footing with respect to De/B ratio for various foundations is shown in figure 10.

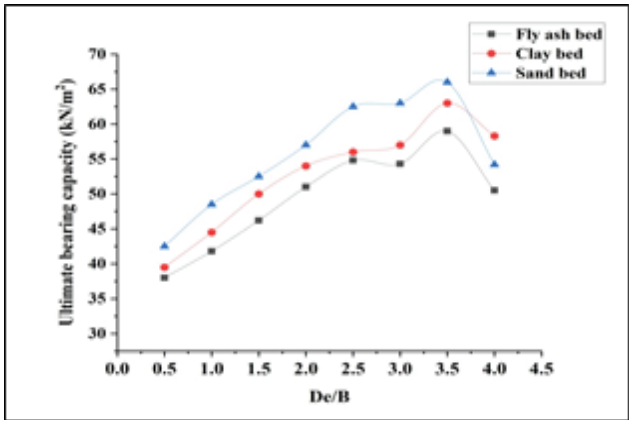

Figure 10: Ultimate Bearing Capacity Vs De/B Ratio for Different Soil Foundations for Stabilized Slope

Figure 10 shows that the maximum ultimate bearing capacity is achieved for sand soil foundations whereas for fly ash foundation bearing capacity is on lower side for a de/B ratio of 3.5, further it can be seen that the bearing capacity falls as the crest to width ratio increases.

Table 6 shows the percentage increase in the ultimate carrying capacity of unstabilized slope with respect to the De/B ratio for different types of soil foundations.

Table 6 Percentage Increase in qu with increase in De/B ratio for Unstabilized Slope

Increase in De/B ratio		0.5-1	1-1.5	1.5-2	2- 2.5	2.5-3	3-3.5	3.5-4
Percent increase in qu	Fly ash bed	8	11.11	3.57	14.94	-3.00	-1.03	-12.50
	Clay bed	8.62	8.47	9.27	15.63	1.35	7.05	-18.15
	Sand bed	8.06	9.85	11.41	17.07	6.25	-1.96	-14.00

Table 7 shows that percentage increase in the bearing capacity is maximum for De/B ratio of 2-2.5 for Fly ash bed, Clay bed and hard bed thereafter there is marginal decrement for further ratios.

Table 7 Percentage Increase in qu with increase in De/B ratio for Stabilized Slope

Increase in De/B ratio		0.5-1	1-1.5	1.5-2	2-2.5	2.5-3	3-3.5	3.5-4
Percent increase in qu	Fly ash bed	15.79	13.64	6.00	3.40	3.10	4.42	-14.41
	Clay bed	12.66	12.36	8.00	3.70	1.79	15.44	-6.08
	Sand bed	19.75	4.12	12.87	9.65	0.80	4.76	-17.88

Table 7 shows that the % increase in bearing capacity for Fly ash beds is greatest when the De/B ratio is 0.5-1 for Fly ash beds and Sand beds, while the percentage increase for Clay beds is greatest when the De/B ratio is 0.5-1.

CONCLUSIONS

After performing Finite Element Analysis for load bearing capacity of stabilized and unstabilized soil slope for different soil foundations following conclusions can be drawn,

- Bearing capacity of strip footing enhances as the crest to width ratio increases upto certain limit thereafter it reduces as the De/B ratio rises further.
- It can be evidently seen that ultimate bearing capacity is found to be optimum when crest to width ratio is 3.5 in stabilized soil slopes. This occurs as a result of soil resistance to lateral displacement increasing when the footing is positioned away from the slope's edge, which creates a wider and deeper failure zone and ultimately raises the footing's bearing capacity.
- For unstabilized case the optimum bearing capacity is observed at De/B = 3.5 for sand bed, whereas for fly ash bed, the UBC is maximum at De/B = 2.5 and that for clay bed it is 3.
- It is discovered that the footing's carrying capability on a clay soil foundation is higher than that of a fly ash soil foundation, but lower than that of a sand soil foundation. This is because the Sand bed has a higher denseness than the fly ash and clay soil foundations, which gives it more resistance to applied pressure.
- In the case of fly ash foundations, stabilized slopes have a greater ultimate bearing capacity than unstabilized slopes and similar trend is observed for clay and sand soil foundations.

The results show that stabilized slopes are more stable than unstabilized slopes, with a 17.43% increase in ultimate bearing capacity.

REFERENCES

1. Adbrabbo F., Gaaver K., Omer E. A., (2008). "Behavior of Strip Footings on Reinforced and Unreinforced Sand Slope". GeoCongress: Geosustainability and Geohazards Mitigations, 25-32
2. Altalhe E. B., Taha M. R. and Abdrabbo F. M., (2015). "Behavior of Strip Footing on Reinforced Sand Slope", Journal of Civil Engineering and Management, 21(3), 376–383
3. Bhargav Kumar K. P. and Umashankar B. (2018). "Interface Studieson Geogrid and Fly Ash" IFCEE 2018 GSP 297 ASCE. 119-129
4. Chakraborty D., Kumar J., (2013). "Bearing Capacity of Foundation on Slopes". Geomechanics and Geoengineering: An International Journal. Vol. 8 No.4, 274-285
5. Dhatrak A.I and Langote R.V., (2024). "Experimental Research on Impact of Fly Ash on Geotechnical Characteristics of Black Cotton Soil", AIP Conference Proceeding 3010, 020007-1-020007-8.
6. El. Sawwaf, (2007). "Behavior of Strip Footing on Geogrid-Reinforced Sand Over a Soft Clay Slope", Geotextiles and Geomembranes 25, 50–60
7. Li Li-Hui, Yu Chang-Dao, Xiao Heng-Lin, Feng Wei-Qiang, Ma Qiang and Yin Jian-Hua (2020). "Experimental Study on the Reinforced Fly Ash and Sand Retaining Wall under Static Load", Construction and Building Material 248 (2020) 118678
8. Nadaf M. B. and Mandal J. N. (2019). "Numerical Simulation of Cellular Reinforced Fly Ash Slopes" Geo-Congress, ASCE 2019 GSP 312, 202-211
9. Nadaf M. B. and Mandal J. N. (2016). "Model Studies on Fly Ash Slopes Reinforced with Planer Steel Grids" International Journal of Geotechnical Engineering, Vol. XX, No. X, 1-12
10. Pant A., Datta M. and Ramana G.V., (2019) "Bottom Ash as a Backfill Material in Reinforced Soil Structure" Geotextile and Geomembranes 47(2019), 514-521

11. Rui Z., Ming-xu L., Tian L., Jian-long Z. and G. Chao, (2020). "Stability Analysis Method of Geogrid Reinforced Expansive Soil Slopes and its Engineering Application", Springer Nature, J. Cent. South Univ. (2020) 27: 1965−1980

12. R. Acharyya and A. Dey, (2017). "Finite Element Investigation of the Bearing Capacity of Square Footings Resting on Sloping Ground". Indian National Academy of Engineering, Vol. 2, 97-105

13. S. Mittal, M. Shah & N. Verma, (2009). "Experimental Study of Footings on Reinforced Earth Slopes", International Journal of Geotechnical Engineering, (2009) 3: 251-260

14. Shejwal K. B. and Gaikwad A.B. (2022) "Generic Analysis of Cohesive Highway Embankment Slope with use of Fly Ash and Geogrids" International Conference on Contents, Computing & Communication (ICCCC)

15. Tahir M. B., Garg P., Grewal G. K., (2021). " Analysis of Load Carrying Capacity of Strip Footing Resting on Geogrid Reinforced Fly-Ash Over an Earthen Slope Using Plaxis2D", Journal of University of Shanghai for Science and Technology, Volume 23, Issue 2, ISSN: 1007-6735, 181-191

16. Thongpetch I. and Chimoye W., (2019). "Behavior of Reinforced Soil Slope by Finite Element Methods". International Journal of Engineering Research & Technology, ISSN: 2278-0181, Vol. 8 Issue 02, 159-163

Enhancing Frictional Properties of Shrink-Swell Soil through GGBF Slag Amendment

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ABSTRACT

Soil serves as a fundamental material for infrastructure construction, acting as the foundation for various structures and dissipating stress intensity. However, not all soils possess sufficient strength to support structures, with some exhibiting low strength and increased compressibility. Shrink-swell soils, in particular, are highly compressible and exhibit negligible frictional properties between particles, resulting in reduced shear strength. Shrink-swell soils exhibit significant volume changes due to their high content of ultra-fine particles, leading to large settlements. Although these soils possess considerable cohesion between particles, their inter-particle friction is essentially zero. To address this issue, industrial waste products can be incorporated into the soil to enhance its shear characteristics, simultaneously minimizing waste disposal. This study investigates the use of Ground Granulated Blast Furnace Slag (GGBFS) as a soil stabilizer to improve the frictional properties of shrink-swell soil. GGBFS powder was mixed with shrink-swell soil in varying proportions (1% to 4.5%) and subjected to direct shear testing. The treated soil's shear strength properties were analyzed, and the strength envelope was plotted to determine the angle of internal friction. The results showed a significant improvement in the angle of internal friction for shrink-swell soil, reaching 40° with the addition of 4.5% GGBFS powder.

KEYWORDS: *Shrink-swell soil, Frictional property, GGBF slag powder, Direct shear test, Angle of internal friction.*

INTRODUCTION

Soil is a vital material in construction, safely transferring superstructure loads to sub-structure foundations. However, shrink-swell soils undergo significant volume changes, compromising building durability. While shrink-swell soils exhibit adhesion properties, essential shear strength characteristic, their frictional properties are notably low [1-4].To enhance soil's shear characteristics, Ground Granulated Blast Furnace (GGBF) slag powder can be added. The GGBF slag's granular particles increase frictional resistance, mitigating shrink-swell soil's limitations. As a byproduct of the steel manufacturing industry, incorporating GGBF slag waste into soil improves shear strength, offering a sustainable solution.

GROUND GRANULATED BLAST FURNACE SLAG

The steel manufacturing process generates slag as a waste product, resulting from the extraction of iron from iron ores and molten iron spills. To solidify the molten slag, it is quenched in water, then ground into a coarse powder (less than 5mm). Traditionally, this by-product is deemed waste and disposed of in landfills, contributing to environmental degradation. However, this slag powder can be repurposed as a valuable soil stabilizing agent. When mixed with shrink-swell soil, it enhances the soil's shear strength characteristics, offering a sustainable solution for construction projects. [5, 6, 7, 8, 9].

FRICTIONAL RESISTANCE OF SHRINK-SWELL SOIL

The frictional resistance, also known as slip resistance, between soil particles determines the soil's ability to resist shear forces. The higher the frictional resistance, the greater the maximum shear force resistance between particles. Shear strength, a critical soil property, depends on two key parameters: Cohesion force (the attraction between particles) Frictional resistance (the force opposing particle sliding. In shrink-swell soils, an imbalance exists: High cohesion force; Negligible frictional resistance this imbalance leads to: High volume changes, High compressibility, Increased susceptibility to shear failure Excessive settlement of structures.[10, 11, 12, 13].

DIRECT SHEAR TEST ON SHRINK-SWELL SOIL

The direct shear test was conducted on untreated shrink-swell soil, with normal and shear stress values tabulated in Table 1. The strength envelope was plotted based on these stresses, allowing for the determination of the angle of shearing resistance from the graph. Additionally, treated shrink-swell soil was tested using a direct shear testing machine to plot its strength envelope. For this treatment, the shrink-swell soil was dried in a hot air oven for 24 hours and subsequently cooled. Ground Granulated Blast Furnace (GGBF) powder was then mixed with the shrink-swell soil in varying percentages, starting from 1% by weight of the soil, to assess the effect on strength. Table 1 also presents the angle of internal friction for the untreated shrink-swell soil, which is measured at 11˚.

Table 1. Direct Shear Test results of untreated shrink-swell soil

S. No	Normal Stress N/ mm2 (σ)	Shear Stress N/ mm2 (τ)	M Value	Angle of Internal Friction in ˚
1	2	0.1	0.198	11.19˚
2	4	0.15		
3	6	0.23		
4	8	0.95		
5	10	1.21		

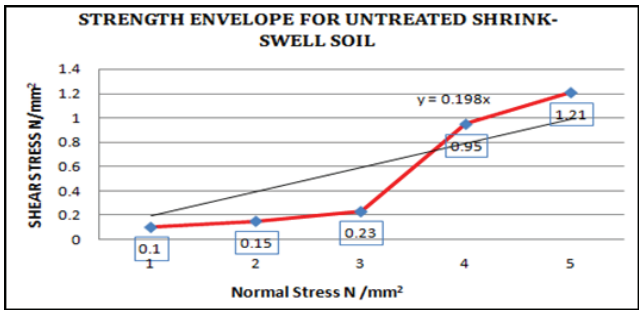

Fig. 1. Failure Envelope for Untreated Shrink-Swell Soil

SHRINK- SWELL SOIL IS A PROBLAMATIC SOIL BEHAVIOUR

Shrink-swell soil is a highly compressible material that undergoes significant volume changes when structures are placed upon it. This can lead to substantial settlement of the structures due to the low hardness of the shrink-swell soil. Consequently, the overall stability of this type of soil is quite low, with an angle of internal friction measured at "0." Figure 2 illustrates the strength envelope for shrink-swell soil, highlighting its unique characteristics and challenges in construction applications.

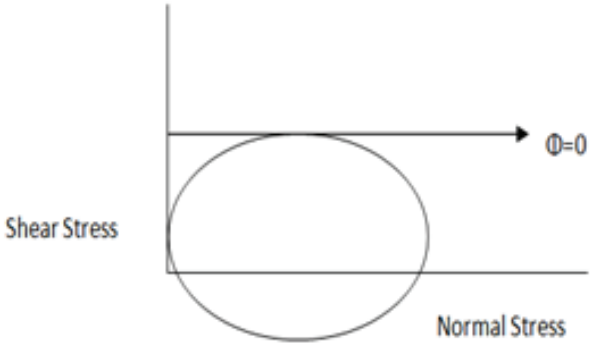

Fig. 2. Angle of Internal Friction of Shrink-Swell Soil

SHRINK- SWELL SOIL TREATED WITH GGBF SLAG

The shrink-swell soil is blended with GGBF slag powder in appropriate proportions. To prepare the soil, it is dried in a hot air oven for 24 hours and then cooled to room temperature. The dried soil is mixed with GGBF powder along with a specific amount of optimal moisture content (OMC), which is determined through compaction analysis.

The optimal moisture content (OMC) is determined using the Proctor compaction test. Figure 3 illustrates the OMC for maximum dry density of shrink-swell soil. This OMC is essential for binding the shrink-swell soil with GGBF slag powder, enabling effective shear testing of the treated soil.

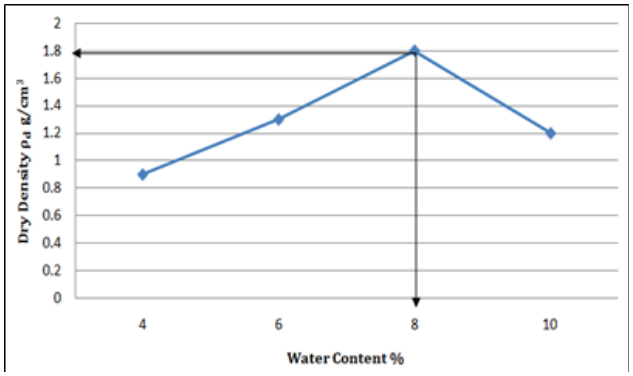

Fig. 3. OMC plot for Shrink-Swell Soil

The optimal moisture content (OMC) for the shrink-swell soil is determined using the standard Proctor compaction test. The maximum dry density of the shrink-swell soil is 1.79 g/cm³, with a corresponding optimum moisture content of 8%. This OMC is used to prepare the soil for better binding with GGBF slag in the shear box apparatus.

The prepared soil is mixed with GGBF slag powder in a proportion of 1% by weight of the soil. This treated soil is placed in the shear box to apply normal and shear loads, allowing for the determination of the maximum failure load and the plotting of the strength envelope for shrink-swell soil.

RESULTS AND DISCUSSIONS

The shear strength of shrink-swell soil is enhanced by adding GGBF slag powder to analyze the internal friction of the soil. Since the frictional resistance in shrink-swell soil is initially zero, incorporating GGBF slag powder improves its frictional properties. This treatment involves adding GGBF slag powder in proportions ranging from 1% to 4.5% by weight.

Table 2 shows the results of the direct shear test for treated shrink-swell soil. The percentage of GGBF slag powder varied from 1% to 4.5% by weight of the shrink-swell soil. An increased percentage of GGBF slag powder leads to a rise in the angle of internal friction of the shrink-swell soil. It is clear that the addition of slag powder enhances the shear strength capacity of the soil.

Table 2. Direct shear test results for treated shrink-swell soil

S. No	% of GGBF Slag Powder	M value	Angle of Internal Friction in °
1	1	0.201	11.36
2	1.5	0.245	13.80
3	2.0	0.301	16.75
4	2.5	0.485	25.87
5	3.0	0.521	27.51
6	3.5	0.731	36.16
7	4.0	0.853	40.46
8	4.5	0.867	40.92

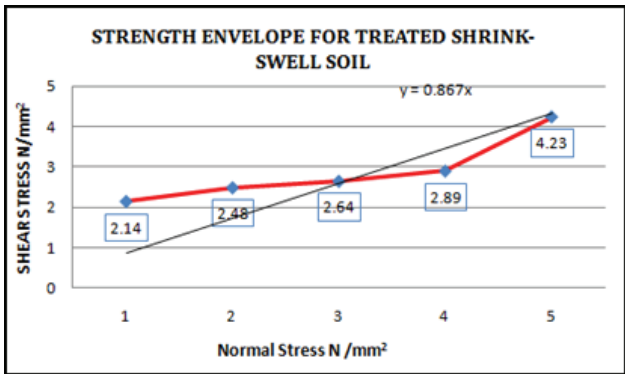

Fig. 4. Failure Envelope for treated Shrink-Swell Soil (4.5% of GGBF Slag powder)

The strength envelope for the treated shrink-swell soil is shown in Figure 4. This envelope is plotted based on the normal stress and shear stress for the treated shrink-swell soil with 4.5% GGBF slag by weight. The angle of inclination of the straight line is measured at 41°. This indicates that the shearing resistance of the shrink-swell soil increases with the addition of GGBF slag powder; specifically, 4.5% GGBF slag powder yields an angle of 40°.

CONCLUSION

The present research explores the use of GGBF slag powder to enhance the frictional resistance of shrink-swell soil. Shrink-swell soil is highly compressible due to its ultrafine particle size distribution and lacks frictional force between the particles. By adding

GGBF slag powder to the shrink-swell soil, the frictional resistance between the particles is improved. Specifically, 4.5% GGBF slag powder yields an angle of shearing resistance of 40°. This research demonstrates that GGBF slag powder, a waste product, can be effectively used as a stabilizing agent for shrink-swell soil.

REFERENCES

1. Amsˇiejus J, Dirge˙liene˙ N, Norkus A, Skuodis S. "Comparison of sandy soil shear strength Parameters obtained by various construction direct shear apparatuses". Archives of Civil and Mechanical Engineering. Vol 14(2), 2014, PP-327–334.
2. ASTM D3080/D3080M-11; Standard Test Method for Direct Shear Test of Soils Under Consolidated Drained Conditions (Withdrawn 2020). ASTM International: West Conshohocken, PA, USA, 2011.
3. Balaban E, Šmejda A, Onur MI. "An experimental study on shear strength behavior of soils under Low confining pressure". Proceedings of the 4th World Congress on Civil, Structural, and
4. Environmental Engineering (CSEE'19). Rome, Italy. April, 2019. DOI: 10.11159/icgre19.110. Chen A, Zhang J. "Strength and deformation characteristics of silty sand improved by gravel". KSCE Journal of Civil Engineering. Vol23 (2), 2019, PP-525–533.
5. AaqibJaved, Syed & Chakraborty, Sudipta. (2020). "Effects of Waste Glass Powder on Subgrade Soil Improvement" World Scientific News144. 30-42.
6. E. Cokca, V. Yazici, V. Ozaydin, Stabilisation of expansive clays using granulated blast furnace slag (GBFS) and GBFS-cement. Journal of Geotechnical and Geological Engineering 27(4) (2009) 489-499
7. H. Canakci, A. Al-Kaki, F. Celik, Stabilization of clay with waste soda lime glass powder. Procedia Engineering 161 (2016) 600-605.
8. R. Benny, J.J. K, J.M. Sebastain, Mariya Thomas. Effect of glass powder on engineering property of clayey soil. International Journal of Engineering Research and Technology 6 (5) (2017) 228-231.
9. J. Wartman, D.G. Grubb, P. Strenk, Engineering properties of crushed glass soil blends. Geotechnical Engineering for Transportation Projects (2004) 732-739.
10. Croft, JB. "The influence of soil mineralogical composition on cement stabilization geotechnique". Vol 17, London, England, (1996).
11. Daniels, J. L; Inyang, H. L; Contaminant barrier material textural response to interaction with aqueous polymers. Journal of Material and Civil Engineering, Vol 16, 2004, PP-365-275.
12. Etim, and etal "Stabilization of black cotton soil with lime and iron ore tailings admixture". TranspGeotech. Vol 10, 2017, PP-85-95.
13. Aaqib Javed, Syed & Chakraborty, Sudipta. (2020). Effects of Waste Glass Powder on Subgrade Soil Improvement. 144. 30-42.

Developing A Smart Village Model for Hashiware Village of Maharashtra

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ABSTRACT

Smart village concept aims to improve the capacity of local communities by utilizing new technologies and providing social solutions in addressing the challenges faced by people. The concept of a smart village includes multiple aspects such as smart security, efficient public transportation system, improving sanitation conditions, solid and liquid waste management, rain harvesting /rain water drainage system, safe drinking water facilities, use of renewable energy, energy conservation, facilities regarding to the agriculture, use of modern technologies for improvement of locality, etc. The present paper focuses on the aspect of solid waste management. Preliminary survey was conducted to find out the present condition of waste management in Hashiware village of Maharashtra. Decentralized waste collection and disposal facility for cluster of 80-100 houses in a village was designed. Solid waste generated in rural areas is predominantly organic and biodegradable hence solar based mechanical composting unit for organic waste was designed which can be used at community level.

KEYWORDS: *Smart village, Solid waste management, Mechanical composter, Waste segregation, Organic waste.*

INTRODUCTION

The basic concept of smart village is to collect community efforts and strength of people from various streams and integrate it with information technology to provide benefits to the rural community. According to Mahatma Gandhi's philosophy and thoughts smart village project provides, "Global means to the local needs." (Somwanshi et al. 2016). The concept of a smart village includes multiple aspects such as smart security, efficient public transportation system, improving sanitation conditions, solid and liquid waste management, rain harvesting /rain water drainage system, safe drinking water facilities, use of renewable energy, energy conservation, facilities regarding to the agriculture, use of modern technologies for improvement of locality, etc. The present paper focuses on the aspect of solid waste management. Government is looking up to Gram Panchayats to come up with a working system to manage solid waste in rural areas.

Smart Villages initiatives are being implemented in both developing and developed countries as a part of national and international programmers for the all-round development of the rural areas (Gerli Paolo, 2021). Management of solid waste is considered as the challenge in rural areas as the waste generated is not segregated. If waste is not disposed properly, it can create unsanitary conditions and can have adverse effects on the health of the human being.

About 70% of India's population, or 750 million, live in its 600,000 villages. The average village has 200-250 households, and occupies an area of 5 sq. km. Most of

this is farmland, and it is typical to find all the houses in one or two clusters. Villages are thus spaced 2-3 km apart, and spread out in all directions from the market towns (Patel & Shah, 2017). There are different aspects of clean village such as: water supply, sanitation, indoor air quality, solid waste management and renewable energy etc. All these aspects have different alternatives with the associated merits and demerits (Kulkarni, 2015). Waste management is a primary and necessary concept in smart and healthy village planning. If the surroundings of human beings can be kept clean, then it can be easier to develop a healthier society. If not properly managed or handled, the waste management techniques can lead to serious environmental problems, and operating costs may increase (Mohanty S. et al., 2020).

OBJECTIVE

The paper focuses on following objectives:

- To conducted a preliminary survey to find out present condition of waste management in the village and collect data about the waste generated per house in Hashiware village.
- To plan for effective door to door waste collection facility for a cluster of 80-100 houses.
- To plan and design decentralized waste collection and disposal facility for cluster of 80-100 houses in a village (total number of houses are 500 plus i.e., total 6 decentralized facility for entire village will be planned)
- To design a solar based mechanical composting unit for organic waste, this can be used at community level.

METHODOLOGY

Conceptual framework of the methodology adopted is shown in Fig.1. The flow chart shows step by step methodology that was followed in the present project.

Data collection has been done about the village through both primary and secondary sources. Survey was conducted to know about the quantity of waste generation per house, type of waste generated, current methodology of solid waste management in the village and existing waste dumping location in the village. Questionnaire was prepared for collecting data as well as interaction with villagers was done to get clear idea about solid waste management. Data was also collected from secondary sources such as gram panchayat.

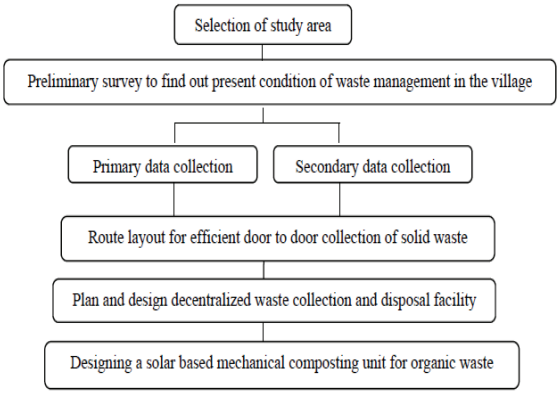

Fig. 1 Methodology

Data collection about waste generation in Hashiware village

Hashiware village is located in Raigad district, Taluka Alibaug. The overall land area of Hashiware village is 765 hectares. Around 500 households are situated in Hashiware Village. According to the 2011 census, the population of Hashiware village was 3644. Survey was conducted and villagers were asked to fill the questionnaire form including owner name, waste generation data in that particular house, type of waste, quantity, and discussion about whether waste disposal is practiced. Study area has been shown in Fig. 2. During the survey it was found that there were total 6 main waste dumping points as shown in Fig. 3. Out of six dumping sites, dumping point 1 was studied in detail and site was identified for mechanical composter unit. Fig. 4 shows existing situation of waste disposal in the study area.

Fig. 2 Location map of village (Source-Google Map)

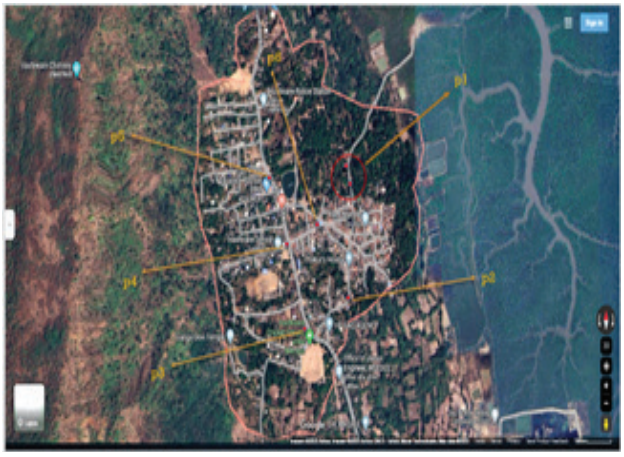

Fig. 3 Dumping points in village

Fig. 4 Existing waste dumping sites

Proposed location of Mechanical composter

Location for mechanical composter unit was finalized based on following criteria:

- Ease of collection and transportation of waste to the dumping site where mechanical composter unit is planned.
- Ease of unloading of waste.
- Site selection for installing mechanical composter unit should be slightly far away from the village community so that odor problem can be avoided.
- Site should not be near to any surface or ground water source.

Based on the above criteria, proposed location of mechanical composter has been shown in Fig. 5.

Fig. 5 Proposed location of mechanical composter

Data analysis

Questionnaire was prepared for the survey and villagers were asked to respond. Based on the responses received, graphical analysis was performed to know the existing situation of waste management in the village. Question on the type of wet waste and dry waste generation was asked. Graphs (Fig. 6 and Fig. 7) shows the type of waste generated in the village. Amongst the wet waste, vegetable peel is generated in huge volume. However, leftover food and garden waste is generated in less volume. Analysis of dry waste shows (Fig. 7) that polythene bag is generated in maximum quantity as compared to other waste such as paper, cardboard, metal, glass and electronic waste. Overall volume of dry waste is less than that of wet waste (Fig. 8).

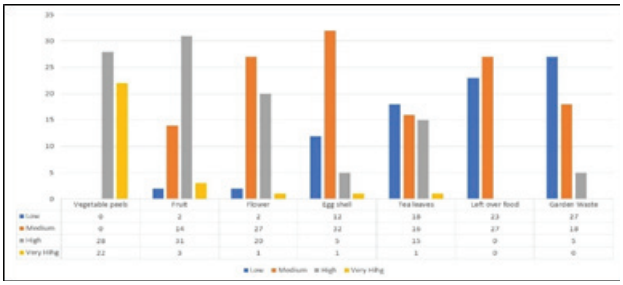

Fig. 6. Wet waste analysis

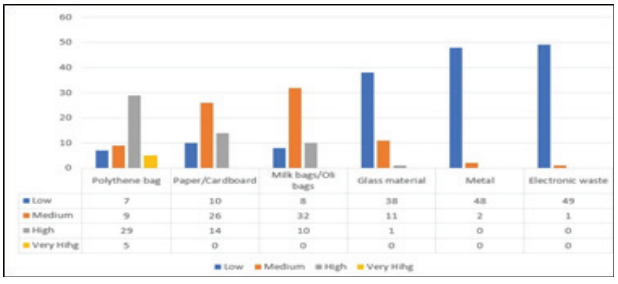

Fig. 7 Dry waste analysis

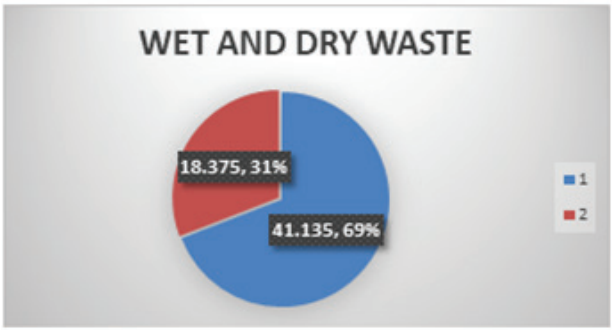

Fig. 8 Wet waste and dry waste generation

Question was also asked on the segregation of waste and existing waste disposal options. It was observed that maximum number of villagers have responded that they do not segregate the waste and dispose the waste in open area (Fig. 9).

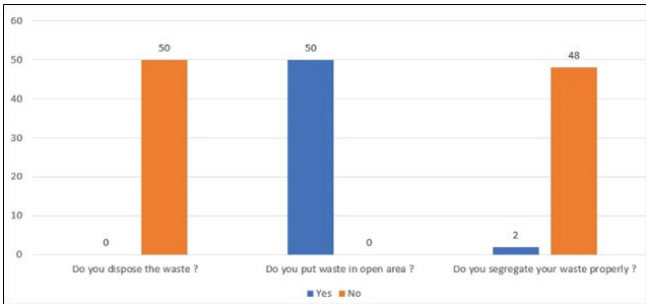

Fig. 9 Disposal of waste

EFFECTIVE SOLUTION FOR WASTE MANAGEMENT IN HASHIWARE VILLAGE

Door to door waste collection facility for a cluster of 80-100 houses was planned for efficient collection of solid waste. Decentralized waste collection and disposal facility for cluster of 80-100 houses in a village was designed. Solid waste generated in rural areas is predominantly organic and biodegradable hence solar based mechanical composting unit for organic waste was designed which can be used at community level.

Solar based Mechanical composter

Composting is the process in which aerobic microorganisms converts organic matter into hygienic, biostable product by thermophilic. This natural process is affected by some environmental conditions like temperature, moisture content, pH and aeration and substrate characteristics like C/N ratio, particle size, nutrients contents and free air space (Shrirao and Hedaoo, 2020). Mechanical composter is considered as an ideal solution for composting all types of organic waste with its operation in the smallest possible place. It is an independent unit that facilitates the composting process and provides better and good quality compost. The proposed mechanical composter is a solar based unit which works with the help of rotating solar panels which would help in entrapping the sunrays within the battery cells of the solar panel (Fig. 10). The manure or compost generated from the composting machine can be used for gardening, planting trees and can be sold for other farming uses. The system includes a Rotating solar panel, shredder, controlling panel, compost pit, motor, ventilation system, and stirring mechanism.

Fig. 10 Prototype of mechanical composter

The wet or organic waste is firstly introduced into the shredder in which it gets crushed into fine and small pieces then afterwards the crushed materials get into the compost pit. Once the shredded material is introduced into the compost pit, the system activates a series of mechanisms to maintain optimal moisture levels, temperature, and aeration, all of which are critical factors for efficient composting. Provision of ventilation is also made for controlling the odor. Natural ingredients can be used as accelerators for the process of composting. Process of composting can be accelerated by using cow

dung, wheat bran, saw dust, eggshell powder, jaggery powder, sugarcane bagasse powder, coconut coir powder, lime powder, neem leaves powder, wooden ash and used tea powder.

CONCLUSION

Solid waste management is a primary and necessary concept in smart and healthy village planning. The present paper focused on providing a comprehensive solution for organic waste management in villages. If the villages are not kept clean, it can lead to serious environmental problems. Solid waste generated in rural areas is predominantly organic and biodegradable hence solar based mechanical composting unit for organic waste was designed. This system overcomes the limitations of conventional composting methods and employs smart moisture and temperature control mechanisms, to optimize composting conditions and accelerate decomposition rates, leading to reduced composting times. It provides shredding mechanisms that ensure the production of high-quality compost. Most importantly it integrates renewable energy sources, such as solar power, hence promotes sustainability and reduces environmental impact, aligning with sustainable development goals.

REFERENCES

1. Somwanshi R., Shindepatil U., Tule D., Mankar A., Ingle N. (2016), Study and development of village as a smart village, International Journal of Scientific & Engineering Research, Volume 7, Issue 6, June-2016 395 ISSN 2229-5518
2. Kulkarni Milind 2015, Clean and Smart Village : Aspects and Alternatives, International Journal of Research in Engineering, Science and Technologies – Civil Engineering, ISSN 2395-6453, Vol. 1, No. 3, June 2015, PP 19-23.
3. Mohanty Sroojani, Mohanta Bhagyashree, Nanda Pragyan, Sen Siddhartha and Patnaik Srikanta (2020), Chapter 1 Smart Village Initiatives: An Overview, © Springer Nature Switzerland AG 2020 S. Patnaik et al. (eds.), Smart Village Technology, Modeling and Optimization in Science and Technologies 17.
4. Paolo Gerli, Julio Navio Marco and Jason Whalle (2021), “makes a smart village smart? A review of the literature”, Transforming Government: People, Process and Policy.
5. Patel, B. N., & Shah, R. (2017). Smart village a case study of Kolavada village. International Research Journal of Engineering and Technology, 4(12), 907-911.
6. Shrirao P.R., Hedaoo M.N. (2020) A Study on Composting by using Natural Accelerating Ingredients, International Research Journal of Engineering and Technology (IRJET), Volume: 07 Issue: 11

Innovative Applications of Nanomaterials in Soil Stabilization and their Impact on Geotechnical Properties

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ABSTRACT

The use of nanomaterials in geotechnical engineering has emerged as a promising approach to enhancing soil stabilization and improving the geotechnical properties of various soil types. This research investigates the innovative applications of nanomaterials, such as nanosilica, nanoclay, and carbon nanotubes, in soil stabilization processes. By incorporating these nanomaterials into traditional soil treatment methods, we aim to address common challenges such as soil erosion, low bearing capacity, and high compressibility.

Through a series of laboratory experiments and field studies, we analyze the effects of nanomaterials on soil strength, permeability, and compressibility. Our findings indicate significant improvements in the mechanical and physical properties of treated soils, including increased shear strength, reduced plasticity, and enhanced durability. The study also explores the environmental impact and cost effectiveness of using nanomaterials compared to conventional soil stabilization techniques.

Furthermore, this research delves into the mechanisms by which nanomaterials interact with soil particles at the microscopic level, providing insights into their role in altering soil behavior. The potential benefits of adopting nanomaterials for largescale geotechnical applications are discussed, alongside the challenges and future research directions needed to optimize their use.

In conclusion, the incorporation of nanomaterials in soil stabilization represents a transformative advancement in geotechnical engineering, offering sustainable and efficient solutions for improving soil performance and infrastructure resilience. This study contributes to the growing body of knowledge on nanotechnology in civil engineering, paving the way for more innovative and effective soil stabilization strategies.

KEYWORDS: *Nanomaterials, Soil stabilization, Geotechnical properties, Nanosilica, Soil strength.*

INTRODUCTION

In recent years, the field of geotechnical engineering has witnessed a surge in innovative approaches aimed at addressing longstanding challenges related to soil stability and performance. Among these, the application of nanomaterials has emerged as a particularly promising avenue. Nanomaterials, characterized by their extremely small particle size and unique physicochemical properties, have the potential to revolutionize soil stabilization techniques, offering enhancements that traditional methods cannot achieve.

Soil stabilization is a critical process in geotechnical engineering, essential for improving the load bearing capacity, reducing permeability, and mitigating the risk of soil erosion and settlement in construction projects. Conventional methods, while effective to some extent, often fall short in terms of durability and environmental impact. This has spurred interest in exploring advanced materials that can provide more sustainable and robust solutions.

Nanomaterials such as nanosilica, nanoclay, and carbon nanotubes have demonstrated exceptional potential in various engineering applications due to their high reactivity, large surface area, and ability to significantly alter the properties of host materials. When applied to soil stabilization, these materials can enhance mechanical properties, reduce plasticity, and improve overall soil behavior under different environmental conditions.

This study aims to explore the innovative applications of nanomaterials in soil stabilization, examining their impact on key geotechnical properties through both laboratory experiments and field studies. By understanding the interactions between nanomaterials and soil particles at a microscopic level, we can uncover the mechanisms driving these improvements and identify best practices for their use in practical applications.

The research also addresses the environmental and economic aspects of using nanomaterials in geotechnical engineering. As the construction industry increasingly seeks sustainable practices, the ability of nanomaterials to offer enhanced performance with potentially lower environmental footprints makes them an attractive option. Furthermore, the study highlights the need for continued research and development to overcome existing challenges and fully harness the capabilities of nanotechnology in soil stabilization.

In conclusion, the integration of nanomaterials into soil stabilization practices holds significant promise for advancing geotechnical engineering. This research contributes to the evolving understanding of how these materials can be effectively utilized, paving the way for more resilient and sustainable infrastructure development.

The primary aim of this research is to explore and evaluate the innovative applications of nanomaterials in soil stabilization, with a focus on their impact on the geotechnical properties of various soil types. By systematically studying the interaction between nanomaterials and soil particles, this research seeks to enhance the understanding of how nanotechnology can be leveraged to improve soil performance and infrastructure resilience in geotechnical engineering.

OBJECTIVES

1. Identify Suitable Nanomaterials: To select and characterize nanomaterials such as nanosilica, nanoclay, and carbon nanotubes for their potential application in soil stabilization, based on their physicochemical properties and compatibility with different soil types.
2. Develop Optimal Mixture Proportions: To determine the optimal concentrations of nanomaterials required to achieve significant improvements in soil stabilization. This involves preparing and testing various soilnanomaterial mixtures to identify the most effective proportions.
3. Evaluate Geotechnical Properties: To conduct a series of laboratory tests (e.g., Atterberg limits, unconfined compressive strength, compaction, and permeability tests) to assess the changes in geotechnical properties of soils treated with nanomaterials compared to untreated control samples.
4. Analyze Microstructural Changes: To use microscopic analysis techniques such as Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) to investigate the microstructural interactions between soil particles and nanomaterials, providing insights into the mechanisms of stabilization.

MATERIALS

The materials chosen for this study were carefully selected to explore the potential of advanced nanotechnology in enhancing soil stabilization. This includes nanomaterials like nanosilica, nanoclay, and carbon nanotubes (CNTs), which offer unique properties such as high reactivity, large surface area,

and exceptional tensile strength. Nanosilica's ability to fill soil voids and bond with soil particles, nanoclay's excellent dispersion properties, and CNTs' flexibility and strength are expected to significantly improve soil stability and mechanical properties. Various soil samples, including clay, silt, and sandy soils, were selected to evaluate the impact of these nanomaterials across different soil types with varying plasticity and permeability. Additionally, distilled water and conventional binding agents like lime and cement were used to prepare consistent and comparable soil-nanomaterial mixtures.

Laboratory equipment such as a mechanical mixer, Standard Proctor compaction apparatus, Atterberg limits equipment, unconfined compressive strength (UCS) testing machine, and permeameter were employed to ensure thorough mixing, determine optimum moisture content and density, and measure geotechnical properties. Microscopic analysis tools like Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) were utilized to observe microstructural changes and interactions between soil particles and nanomaterials. These tools provide detailed insights into the mechanisms of soil stabilization at the nanoscale, helping to achieve a comprehensive understanding of the effects of nanomaterials on soil properties.

METHODS

This study employs a comprehensive approach to investigate the impact of nanomaterials on soil stabilization, combining laboratory experiments, field tests, and analytical techniques. The research begins with the selection of appropriate nanomaterials, including nanosilica, nanoclay, and carbon nanotubes, known for their effectiveness in enhancing material properties. Soil samples representing various types such as clay, silt, and sandy soils were collected to ensure the broad applicability of the results. The nanomaterials were then mixed into the soil samples at varying concentrations to determine the optimal dosage for stabilization. Laboratory tests, including Atterberg limits, unconfined compressive strength (UCS), standard Proctor compaction, and permeability tests, were conducted to evaluate the geotechnical properties of treated and untreated samples. Microscopic analyses using Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) provided insights into the microstructural changes and interactions between soil particles and nanomaterials.

To validate the laboratory findings, field tests were performed on larger soil volumes treated with the optimal nanomaterial concentrations identified in the lab. These tests included plate load tests and in-situ permeability assessments to measure bearing capacity and soil permeability under real-world conditions. An environmental impact assessment evaluated the sustainability of using nanomaterials in soil stabilization, analyzing potential leaching, long-term stability, and ecological risks. A cost-benefit analysis compared the economic viability of nanomaterial-based methods with traditional techniques, considering material costs, application expenses, and long-term benefits. The data from these tests were statistically analyzed to identify significant improvements, and regression models were developed to predict the behavior of nanomaterial-treated soils. The study concludes with practical recommendations for using nanomaterials in geotechnical engineering and identifies future research areas, ensuring valuable insights for both academia and industry.

PREPARATIONS

The preparation phase of this study is crucial for ensuring accurate and reliable results, involving a systematic approach to collecting and preparing soil samples, incorporating nanomaterials, and setting up the necessary equipment for testing. This meticulous preparation process sets the foundation for meaningful and reproducible results in subsequent testing and analysis phases.

Collection and Preparation of Soil Samples

Soil samples were collected from various locations to ensure a diverse range of soil types, including clay, silt, and sandy soils. Each sample was carefully labeled and stored in airtight containers to maintain its original moisture content and properties. The collected soil samples were sieved to remove any debris and larger particles and classified according to the Unified Soil Classification System (USCS). This classification

helped in identifying the specific properties of each soil type, tailoring the nanomaterial treatment accordingly.

Selection and Preparation of Nanomaterials

Nanosilica, nanoclay, and carbon nanotubes (CNTs) were chosen due to their proven effectiveness in enhancing material properties. Nanosilica was characterized for its particle size and purity, weighed accurately for different concentrations (0.5%, 1%, and 2% by weight), and stored in sealed containers to prevent contamination. Similarly, nanoclay was sourced and its properties verified. CNTs were handled with care due to their fine nature and potential health hazards, with appropriate safety measures taken during preparation.

Mixing of Nanomaterials with Soil Samples

Before mixing, the moisture content of each soil sample was adjusted to its optimum level as determined by the Standard Proctor Compaction Test. This ensured consistent mixing and compaction. The measured nanomaterials were gradually added to the soil samples and mixed using a mechanical mixer until a homogeneous mixture was achieved, ensuring even distribution of nanomaterials throughout the soil. The prepared soil-nanomaterial mixtures were placed in airtight containers and allowed to cure for a specified period, enabling the nanomaterials to interact with the soil particles, enhancing the stabilization process.

Equipment Setup and Calibration

All laboratory equipment, including the Standard Proctor Compaction Apparatus, UCS Testing Machine, and Permeameter, were calibrated before use to ensure accuracy and reliability of the test results. The Scanning Electron Microscope (SEM) and Transmission Electron Microscope (TEM) were prepared for analyzing the microstructural changes in the treated soil samples. Samples were carefully prepared for microscopic examination, ensuring no contamination or alteration of their structure.

Safety and Environmental Considerations

Proper safety protocols were followed throughout the preparation process, including the use of personal protective equipment (PPE) such as gloves, masks, and safety goggles, especially when handling nanomaterials. Measures were taken to prevent any environmental contamination during the preparation and mixing processes. Waste materials were disposed of according to safety regulations, and all experiments were conducted in a controlled laboratory environment.

Preliminary Testing

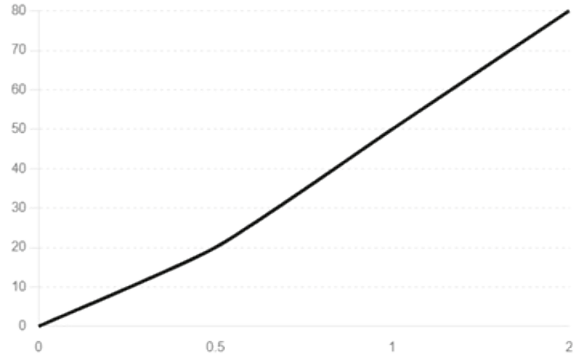
Initial tests were conducted on untreated soil samples to establish baseline geotechnical properties, providing a reference point for comparing the effects of nanomaterial treatment. Preliminary mixes of soil and nanomaterials were prepared and tested to refine the mixing ratios and procedures, helping to optimize the preparation process and ensure consistency across all samples.

RESULTS

The study revealed significant improvements in the geotechnical properties of soils treated with nanomaterials. The Atterberg Limits Test showed a marked reduction in the plasticity index, indicating increased stability. The Unconfined Compressive Strength (UCS) Test demonstrated a substantial increase in soil strength, with nanosilica-treated clay showing a 50% increase in strength. The Standard Proctor Compaction Test indicated a decrease in optimum moisture content and an increase in maximum dry density. Permeability tests showed a significant reduction in soil permeability, with silt soils treated with 2% nanoclay experiencing a 60% decrease in permeability. SEM and TEM analyses revealed that nanomaterials effectively filled voids and formed a dense, cohesive matrix within the soil. Field tests, including the Plate Load Test and in-situ permeability assessments, confirmed the laboratory findings, demonstrating the practical applicability of nanomaterial treatments in real-world conditions.

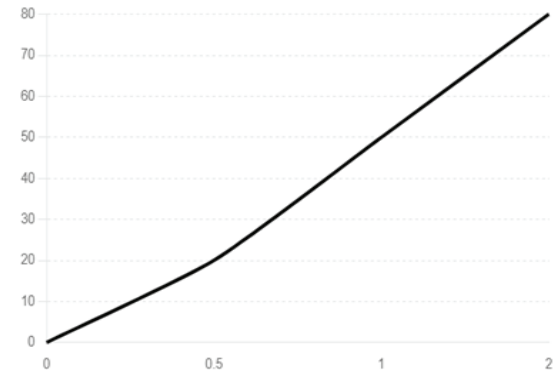
Field Test Procedures: The Plate Load Test and in-situ permeability tests were conducted to validate laboratory findings. The Plate Load Test involved preparing the site, excavating a pit, placing the bearing plate, setting up the loading equipment, and measuring the load-settlement curve. The in-situ permeability test involved site preparation, installing a permeameter, saturating the soil, and measuring the hydraulic conductivity using Darcy's law. These field tests provided valuable data to assess the performance of nanomaterial-treated soils in practical applications. Safety and Environmental Considerations:

By following these detailed procedures, field tests can effectively validate the laboratory results and provide practical insights into the performance of nanomaterialtreated soils in realworld applications.



X =Nanomaterial Concentration (%)
Y= Reduction in Plasticity Index(%)

Fig. 1 Reduction in Plasticity Index with Nanomaterial Concentration



X= nanomaterial Concentration(%)
Y= Increase in UCS(%)

Fig. 2 Increase in Unconfined Compressive Strength with Nanomaterial Concentration

These diagrams visually represent the impact of nanomaterial concentration on soil properties, demonstrating the enhancements in geotechnical performance.

DISCUSSIONS

The results of this study underscore the potential of nanomaterials to revolutionize soil stabilization practices in geotechnical engineering. The observed improvements in geotechnical properties can be attributed to the unique characteristics of nanomaterials, such as their high surface area, reactivity, and ability to interact at the microscopic level with soil particles.

Mechanisms of Improvement

Particle Binding and Void Filling: Nanomaterials like nanosilica and nanoclay enhance soil stability by filling voids and binding soil particles together. This leads to a denser and more cohesive soil matrix, which improves compressive strength and reduces plasticity and permeability.

Reinforcement by Carbon Nanotubes: Carbon nanotubes provide a reinforcing effect within the soil, akin to adding a fibrous network. This reinforcement significantly enhances the mechanical properties of the soil, making it more resilient to external loads and stresses.

Environmental and Economic Considerations

The environmental impact assessment indicated that the use of nanomaterials in soil stabilization is relatively safe, with minimal leaching observed during the tests. Moreover, the costbenefit analysis demonstrated that, despite the higher initial cost of nanomaterials, the longterm benefits, such as reduced maintenance and enhanced durability, make this approach economically viable.

Practical Implications

The findings of this study have significant practical implications for geotechnical engineering. Nanomaterialtreated soils offer a sustainable and effective solution for infrastructure projects, particularly in areas with problematic soils. The enhanced properties of these soils can lead to safer and more durable foundations, embankments, and other geotechnical structures.

Future Research Directions

While the results are promising, further research is needed to optimize the use of nanomaterials in soil stabilization. Longterm performance studies, the development of standardized application methods, and the exploration of new nanomaterials with enhanced properties are essential next steps.

In conclusion, the innovative application of nanomaterials in soil stabilization presents a transformative advancement in geotechnical engineering. The significant improvements in soil properties observed in this study highlight the potential

for nanotechnology to contribute to more resilient and sustainable infrastructure development.

CONCLUSION

The incorporation of nanomaterials in soil stabilization marks a significant advancement in geotechnical engineering, providing effective solutions to challenges related to soil stability and performance. This study highlights the profound impact of nanomaterials such as nanosilica, nanoclay, and carbon nanotubes on the geotechnical properties of various soil types. Laboratory and field tests confirm that these nanomaterials enhance soil strength, reduce plasticity, and significantly lower permeability. These improvements are attributed to the unique properties of nanomaterials, which enable them to interact at the microscopic level with soil particles, filling voids and creating stronger bonds. The increased unconfined compressive strength and reduced plasticity index observed in this study highlight the potential of nanomaterials to improve the load-bearing capacity and overall stability of treated soils.

Field tests further validate these laboratory findings, demonstrating the practical applicability of nanomaterial-treated soils under real-world conditions. Plate load tests showed substantial increases in bearing capacity, while in-situ permeability tests confirmed significant reductions in soil permeability, underscoring the viability of using nanomaterials for large-scale geotechnical projects, particularly in areas with challenging soil conditions. Environmental and economic assessments indicate that despite the initial higher costs, the long-term benefits of using nanomaterials—such as reduced maintenance requirements and enhanced durability—make this approach sustainable and cost-efficient. However, the study also identifies the need for further research to optimize nanomaterial use in soil stabilization, including long-term performance monitoring, the development of standardized application methods, and the exploration of new nanomaterials with enhanced properties. Overall, this research offers valuable insights into the mechanisms and benefits of nanomaterial-treated soils, paving the way for future advancements in geotechnical engineering.

REFERENCES

1. Zhang, M., Zhao, M., & Meng, D. (2016). "Effect of nanosilica on the properties of cementbased materials: A comprehensive review." Construction and Building Materials, 102, 5164.
2. Liu, R., Zhang, L., & Gao, W. (2017). "Utilization of nanoclay in soil stabilization for sustainable development: A review." Journal of Cleaner Production, 142, 41934205.
3. Ghobadi, M., Azarafza, M., & Hosseini, S. A. (2019). "Application of carbon nanotubes in improving the mechanical properties of clayey soils." Geotechnical and Geological Engineering, 37(4), 26572668.
4. Alakhras, N. M., abudieyeh, M., & Shweikat, Y. (2008). "The effect of nanoclay on the mechanical properties of stabilized soils." Applied Clay Science, 38(12), 4957.
5. Singh, D., & Kumar, A. (2018). "Nanotechnology in soil stabilization: An overview." Materials Today: Proceedings, 5(9), 2051920526.
6. Modarres, A., & Nosoudy, Y. M. (2015). "Clay stabilization using coal waste and lime—Technical and environmental impacts." Applied Clay Science, 116117, 281288.
7. Kumar, V., & Gupta, R. (2016). "Soil stabilization using nano materials: A review." International Journal of Innovative Research in Science, Engineering and Technology, 5(6), 1003310040.
8. Mirhosseini, S. R., & Kolahchi, R. (2019). "Stabilization of expansive soils using nanosilica: A microstructural approach." Construction and Building Materials, 220, 6676.
9. Mahdavi, A., & Hosseinpour, I. (2020). "Improving the geotechnical properties of silty sand using nanosilica." Transportation Geotechnics, 25, 100405.
10. Rao, K. S., & Rajasekaran, G. (2016). "Effect of nanomaterials on geotechnical properties of marine clays." Ocean Engineering, 127, 4553.

Continuous Improvement Methodology (KAIZEN) for Improving Product Quality, Casting Yield and Minimize Rejection -A Case Study in Small Scale Foundry Industry

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ABSTRACT

Metal casting is considered as one of the earliest and most significant industrial processes in history. It plays a vital role in producing numerous metal items we encounter daily, such as automotive components, machinery parts, agricultural and countless others. Small and Medium Enterprises (SMEs) form a vital part of India's economy, contributing significantly to its industrial output, exports, and employment generation. SMEs constitute the foundation of the country's economic advancement and account for around 30% of India's Gross Domestic Product. There are around 4,500 foundries in India, of which approximately 85-90% are categorized as SMEs. For many small and medium size foundries, especially conventional foundries managed by traditional push systems, lean manufacturing provides an innovative management approach for organizations to improve their processes, including casting quality and yield. Hence, in this paper, an attempt has been undertaken to implement Lean Manufacturing Philosophy utilising KAIZEN as a tool for enhancing product quality by reducing defects and improving casting yield.

KEYWORDS: *Lean manufacturing philosophy, KAIZEN, Total productive maintenance, Single minute exchange of die, Just in time, Casting yield.*

INTRODUCTION

Lean manufacturing is a philosophy focused on eliminating waste that does not add value to processes, through continuous improvement in products and processes, while striving for perfection. Singh et al. [1] has mentioned that Lean Manufacturing system assists firms to sustain in Competitive Market by Optimizing its performance for superior quality; on time delivery with lower cost. Singh et al. [2] observed that many businesses in India are now facing the pressure of global competition, which has motivated them to take significant steps toward adopting Lean Manufacturing. Mishra et al. [3] explained that the concept of Lean Manufacturing aims to reduce production lead time, cut costs, enhance quality, and minimize inventories within the manufacturing system. Major 7 types of wastes are identified in LMP: overproduction, inventory, waiting, motion, defects, over-processing, and transportation. These wastes do not contribute any value to the product or service that the customer is willing to pay for. In the lean manufacturing philosophy, these seven types of waste are addressed using 12 techniques, including Kaizen, 5S, JIT, Visual Management, VSM, Andon, Gemba, TPM, Takt Time, SMED, SCM, and Cellular Layout. These 12 Lean manufacturing tools can serve as an effective organizational strategy for the metal

casting industry, driving continuous improvement in product and process to reduce defects, enhance quality, and increase casting yield. However, despite the numerous benefits of lean manufacturing, its successful implementation in the small and medium sized foundry remains challenging due to-lack of knowledge and awareness of the lean concepts and the purpose of lean practices, lack of knowledge for using proper tool to solve or apply for specific problem, lack of expertise and training, lack of technical know-how. Khadse et al. [4] explain that manufacturers in the Indian industry have consistently encountered significant challenges, including rising customer expectations, demand fluctuations, and market competition. Darbari et al. [5] identify that one of the primary reasons for the ineffective implementation of Lean Manufacturing is the focus solely on tools and techniques, while overlooking the human factor. Nordin et al. [6] stated that, the ultimate goal of a Lean organization is to establish a streamlined and high-quality system capable of producing finished products that meet customer demands, with acceptable quality and no waste. This paper mainly focused on the Continuous Improvement Methodology (KAIZEN) for improving Product Quality, casting yield and minimize rejection in a Foundry Industry. The production, defect, inspection data of six month is collected to evaluate the performance of foundry. The case study was conducted Kohinoor Metallics Pvt Ltd., a small-scale foundry located in Shiroli MIDC, Kolhapur district, Maharashtra, India. The primary goal of the study was to achieve continuous process improvement by minimizing waste and enhancing quality and casting yield.

KAIZEN AS A TOOL FOR STUDY

The phrase KAIZEN originates from two Japanese terms, 'Kai' and 'Zen,' collectively signifying "good change" or "improvement." Kaizen means "continuous improvement" where all employees in the organisation actively involve and engage themselves in improving the product/process/services done in the industry. Employees at all level of management (Top level to bottom level) come together and work proactively to achieve regular, incremental improvement in manufacturing. KAIZEN is one of the effective tool in Lean Philosophy generally used in in all types of manufacturing industry. Implementation of the Kaizen tool does not require significant financial investment, yet it provides substantial benefits. In small to medium sized foundries, where the manufacturing process involves casting the molten metal in various shapes, there are many opportunities for small, incremental changes that can lead to substantial improvements over time. LMS was an alternative approach to production systems focused on eliminating waste through continuous improvement [7]. Khot et al. [8] explained that, in the Lean manufacturing philosophy, it is essential for members from all departments or sectors within the industry to be involved, with everyone being thoroughly educated about its fundamentals, philosophy, implementation methodology, and benefits.

RESEARCH METHODOLOGY

The purpose of this study is to explore the application of lean manufacturing-KAIZEN tool within small- to medium-sized foundry. The main steps of work: 1. Study of manufacturing processes in a small-scale foundry.2. Identification of issues within the foundry and areas with potential for improvement.3. Analysing the various causes of problems by (why-why analysis) technique. 4.Implementing the lean manufacturing tool (KAIZEN).5. Result of measurement.

SURVEY OF FOUNDRIES IN KOLHAPUR DISTRICT

Conducting a survey to implement Kaizen in a foundry is a great way to gather input from employees, identify areas for improvement, and assess the readiness for change. Thus, a survey was conducted in 30 foundries located in Shiroli MIDC, Kolhapur. A set of questionaries was prepared for survey which include information related to organisation background, motivation and challenges for implementing lean, Barriers to implement LM tools, Effectiveness of Lean tools in organisation, Drivers of Lean Activities, Employee awareness and training, team work, quality planning and control, Workplace culture and employee awareness, Employee recognition and rewards etc. There responses were rated on a Likert scale of 1 to 5, where 1 indicates "Strongly Disagree," 2 indicates "Disagree," 3 indicates "Undecided/Neutral," 4 indicates "Agree," and 5 indicates "Strongly Agree."

Table 1. Sample survey response sheet for Barriers to implement LM Tools

Barriers to implement Lean manufacturing tools

Barriers to implement Lean manufacturing tools											
1	2	3	4	5					NA		
Strongly disagree	Disagree Agree	Undecided	Agree	Strongly					Not applicable		
There is little interest in changing or adopting lean in company				1	2	3	4	5	N/A		
There is not enough expertise on how to implement lean activities				1	2	3	4	5	N/A		
There is resistance to generating new measurements of improvement for lean activities				1	2	3	4	5	N/A		
Middle management resists implementing lean activities				1	2	3	4	5	N/A		
Employee staff resist implementing lean activities				1	2	3	4	5	N/A		
Implementing lean would pose a challenge to our workplace culture				1	2	3	4	5	N/A		
There is not enough time for the company to currently implement Kaizen activities				1	2	3	4	5	N/A		
There were a small amount and only poor experiences with past lean projects				1	2	3	4	5	N/A		
There is a lack of technological capability to be able to implement Kaizen activities				1	2	3	4	5	N/A		
Financial resources that are dedicated for Kaizen projects are fairly limited into the company				1	2	3	4	5	N/A		

From the result of the study we concluded that many small to medium sized foundries in Kolhapur are committed to implement Lean manufacturing philosophy but have few misconception such as- Implementing Lean requires significant financial resources and sophisticated technology, lean implementation is a top-down initiative that only involves management, lean principles are too complex or only suited for large-scale or high-tech industries, foundry operations are too unique or complex for lean practices to work effectively, foundry workers hesitate implementation of lean practices due to their comfort with traditional methods. Based on collected data after survey, we selected to select Kohinoor Metallics Pvt. ltd, Kolhapur for study. Major focus of study was to improve the casting quality, casting yield and minimise the defects. Thus, KAIZEN as a tool was decided for implementation of LMP.

A CASE STUDY: APPLICATION OF LEAN MANUFACTURING TOOL (KAIZEN)

Case Study: I

Section: Core Shop Part name: Pump head 5.5

Problem Identified: Pump head 5.5 castings exhibit poor surface quality, sand drop, and excess material, requiring additional fettling time and occasionally leading to rejection. Additionally, core slot/rib burning during the core burning process is observed due to inadequate thickness.

Objective: 1. To minimise the fettling time and improve surface finish of casting. 2. To do necessary core rib size correction. 3.To minimise the rejection due to sand drop, fusion etc.

Action taken / Remedies: Conduct a detailed inspection of the core making process and Why-Why analysis was used to identify factors contributing to poor surface and sand drop and recommended painting of core to get good surface finish. Ensure proper compaction of sand to avoid loose areas causing sand drop. Inspected sand quality (grain size, binder composition) for consistency. Review the design of the core slot/rib to assess whether the thickness meets functional and process requirements. Collaborate with design engineers to increase the thickness of the core slot/rib from 5mm up to 10 mm to prevent burning.

Before

After

Fig. 1. Before and after applying core slot/rib size

Improvement due to KAIZEN activity

1.Eliminate sand fusion defect.2. Increased casting surface finish.3. Reduce fettling time by 110 seconds. 4.Reduce cost associated with fettling.5. Timely delivery of the casting.

Case Study – II

Section: Pouring Part Name: Bowl 705444

Problem Identified: 1. Castings rejection due to shrinkage defect. 2.Insufficient metal feeding.3. Low

yield percentage of casting.4. Difficulty in de gate/ fettling of casting.

Objective: 1. To eliminate the shrinkage defect responsible for casting rejection. 2. To increase casting yield and reduce the overall bunch weight of Bowl 705444.

Action taken / Remedies: During the study, it was observed that the side pouring method used to feed molten metal into the casting caused insufficient metal feeding due to an inadequate gating system. To address this, the gating system design for Bowl 705444 was reviewed to analyse the passageway through which molten metal flows into the mould cavity. In collaboration with design engineers, it was decided to redesign the gating system, incorporating a centre pouring method and replacing the 90 x 200 mm pouring sleeve with a 70 x 175 mm pouring sleeve. This change resulted in the uniform distribution of molten metal through the ingates into the cavity. Centre pouring sleeve also act as a feeder head to feed the molten metal back as the casting starts solidifying to minimise the shrinkage.

After

Fig. 2 Centre Pouring Sleeve

Improvement due to KAIZEN activity: 1. Eliminate the shrinkage defect.2. Increase casting yield by 6.82%3. Reduce casting bunch weight by 6 kg.4.Easily remove the gating system from the casting using a simple hammering method, eliminating the need for a cutting wheel that was previously required.

Result

Table 2. Result in casting yield improvement and reduction in bunch weight

Improvement parameter	Before	After
Casting yield	79.60%	72.78%
Bunch Weight	70 kg	64 kg

Case Study : III

Section: Core shop Part Name: Cover M80

Problem Identified: Shrinkage defects were observed in the Cover M80 casting, leading to rejection during the casting inspection. Improper feeding of molten metal due to an inadequate gating system design.

Objective: 1. To resolve the issue of shrinkage defects in the Cover M80 casting to reduce rejection rates and improve product quality. 2.To redesign the gating system to ensure proper feeding of molten metal, preventing localized shrinkage and ensuring uniform metal flow. 3.To minimize casting rejections due to shrinkage by refining the gating system, leading to higher overall casting yield.

Action taken / Remedies: 1. Design an overlap gating system and increase the face machining allowance by 2.5 mm to improve metal flow and reduce defects. Additionally, shift the sand shooting hole position to enhance Mold filling. 2.The new core weight will be 1.099 kg.

Before

After

Fig. 3. Before core design and after core design

Improvement due to KAIZEN activity: 1. Eliminate shrinkage defect.2. Reduce core weight by 0.100 kg.3. Eliminate sand wash issue 4. Reduce casting rejection.

Case Study - IV

Section: Core Shop

Problem Identified: A flat round breaker core was used for the sleeve base. This design caused casting damage during the removal of the sleeve riser. Additionally, the core's inner diameter (ID) of 45 mm created a hot spot area, leading to shrinkage defects in the casting.

Objective: 1. To redesign the core design to eliminate the hot spot area and shrinkage defect in casting. 2.Eliminate casting profile damage.

Action taken: Modify the breaker core design by creating a new core box with a V-shape to facilitate easier removal of the sand riser. Additionally, reduce the core diameter to 35 mm for improved performance.

Before

After

Fig. 4. Before and after core design

Improvement due to KAIZEN activity

1.Shrinkage not observed.2. Hot section minimised.3. Due to V shape , easy removal of sleeve riser fettling process.4.RR cutting process totally eliminated.

Case Study - IV

Section: Core shop Part Name: Pump housing 50/160

Problem Identified: During the pouring process, no suction effect is observed on the sand riser, potentially indicating issues in the feeding system or gating design. Presence of extra material in the bore, which affects overall performance.

Objective: 1. To improve the casting bore surface finish. 2. To improve the hardness of core.

Action taken / Remedies: Modify the core-making process by switching to cold box core manufacturing and applying alumina paint instead of graphite paint to achieve improved surface finish quality.

Before

After

Fig. 5. Before and after core design of Pump Housing 50/160

Improvement due to KAIZEN activity: 1. Improved core surface finish.2. Increase core scratch hardness.3. Eliminate core spongy defect.4.Extra material in bore was eliminated.

CONCLUSION

Global competition is pushing foundry industries to face significant challenges in delivering high-quality castings, customized products at lower costs to meet the soaring market demands. Kaizen has emerged as an effective tool to tackle these challenges. By identifying and eliminating defects, it enhances process efficiency, leading to improved product quality and higher casting yields. This study applies the Kaizen methodology to reduce the rejection rate of castings in the foundry industry. The results reveal a reduction in the casting rejection rate which significantly lowering the cost. Kaizen has proven to be an effective and essential tool for lean manufacturing, enabling small and medium-sized foundries to grasp and consistently improve their understanding of lean. This study presents a case example of how implementing the Kaizen approach can enhance productivity in the foundry industry by improving product quality, increasing casting yield, and reducing defects.

REFERENCES

1. Singh B., Garg S.K., Sharma S.K, (2009), Lean can be a survival strategy during recessionary times"", International Journal of Productivity and Performance Management, Vol. 58 Issue: 8 pp. 803 - 808."
2. Singh B., Garg S.K., Sharma S.K, (2010), Scope for Lean implementation: a survey of 127 Indian industries"", International Journal of Rapid Manufacturing, Vol. X, No. Y, pp1-11."
3. Mishra O.P., Kumar V. Garg D., (2013)," JIT supply chain: An investigation through general system theory" Management Science Letters Volume 3 Issue 3 pp. 743-752 ,2013.
4. Khadse Priti B., Sarode Avinash D. and Wasu Renu (2013), Lean Manufacturing in Indian Industries: A Review"" Vol. 3 Issue 1 September 2013, International Journal of Latest Trends in Engineering and Technology ISSN: 2278-621X, pp 175-181."
5. Darabi R, Moradi R. & Toomari U. (2012), Barriers to Implementation of Lean Accounting in Manufacturing Companies"", International Journal of Business and Commerce Vol. 1, No. 9, pp 38-51."
6. Nordin N, Baba Md Deros and Dzuraidah Abd Wahab, (2010) A Survey on Lean Manufacturing Implementation in Malaysian Automotive Industry"", International Journal of Innovation, Management and Technology, Vol. 1, No. 4, October 2010 ISSN: 2010-0248 Pp 374-380."
7. T. Papadopoulou and M. O¨ zbayrak, "Leanness: experiences from the journey to date," Journal of Manufacturing Technology Management, vol. 16, no. 7, pp. 784–807, 2005.
8. Khot, J. A., Tamboli, J. A., & Reddy, A. S. (2019). Application of lean manufacturing with KAIZEN tool in a small-scale industry- A case study in foundry. Manufacturing Technology Today, 18(5), 15–20.

Geometric Optimization of Flexure Bearings for Miniature Moving Magnet Compressors using FEA and L9 Orthogonal Array for Pulse Tube Cryocooler

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ABSTRACT

Purpose – This research aims to enhance the design of flexure bearings for miniature moving magnet compressors utilized in pulse tube cryocoolers. These bearings are crucial in precision engineering, providing controlled flexural movement with minimal friction.

Findings – The investigation revealed that hexagonal flexure bearings exhibit superior radial and axial stiffness compared to their square and pentagonal counterparts. The transition from Beryllium copper to the more economical stainless steel 310 proved to be effective without significantly sacrificing performance.

Design/methodology/approach – We conducted a comparative analysis of three geometric configurations—square, pentagonal, and hexagonal—using Finite Element Analysis to evaluate their performance under varying load conditions. Although Beryllium copper was initially selected for its excellent properties, the high cost led to the adoption of stainless steel 310. The flexure bearings were constrained to a 50 mm diameter. Further analyses focused on optimizing geometry, thickness, and slot width using the Taguchi method with an L9 orthogonal array to determine the impact of these parameters on performance.

Originality/value – This study presents a comprehensive framework that integrates FEA with the Taguchi method to optimize the design of flexure bearings, enhancing both performance and cost-efficiency. The findings significantly contribute to improving the efficiency and reliability of miniature moving magnet compressors, advancing pulse tube cryocooler technology.

KEYWORDS: *Flexure bearing, Finite Element Analysis, Miniature moving magnet Compressor, Pulse tube cryocooler.*

INTRODUCTION

Flexure bearings play a pivotal role in precision engineering applications, particularly within pulse tube cryocoolers where they enable controlled mechanical movement with minimal friction. These bearings are essential components in miniature moving magnet compressors, critical for achieving reliable and efficient operation in cryogenic environments. Optimizing the design of flexure bearings to enhance their axial and radial stiffness is crucial for improving overall system performance. The use of clearance seals in linearly driven miniature cryocoolers has tremendously increased because of its wear free and frictionless operation. Reliability and life of such units are high as compared to contact type seals (Patel et al., 2018). This study focuses on the geometric optimization of flexure bearings using advanced methodologies such as Finite Element Analysis (FEA) and the Taguchi method with an L9 orthogonal array (Chen etal., 2019). Geometric considerations, the study addresses the practical aspects of material selection. While Beryllium copper initially offered excellent mechanical properties, its high cost prompted an investigation into alternative materials. Stainless steel 310 emerged as a viable option due to

its favorable balance of performance characteristics and cost-effectiveness, aligning well with the optimization goals of the study (Kumar & Sharma, 2020). By enhancing axial and radial stiffness, the optimized bearing design contributes directly to improving the efficiency, reliability, and longevity of miniature moving magnet compressors in pulse tube cryocoolers. The methodologies employed, key findings, and practical implications of optimizing flexure bearings for cryogenic applications. It aims to provide valuable insights for researchers and engineers involved in the design and enhancement of precision components in advanced cryogenic systems (Lee et al., 2021). Figure 1 Show location of Flexure Bearing in Miniature Moving Magnet Compressor.

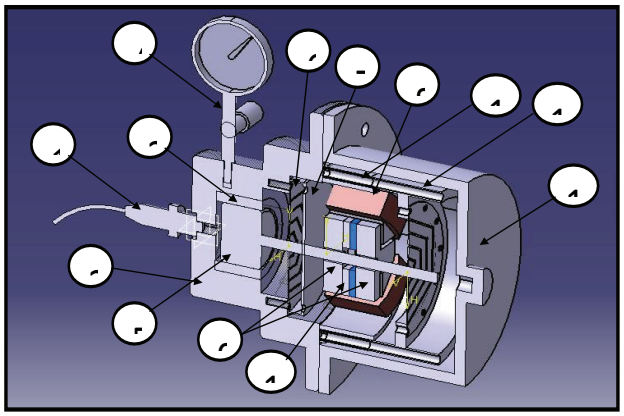

Fig. 1: Location of Flexure Bearing in Miniature Moving Magnet Compressor

Design requirements of Flexure bearing

There are three design requirements that should be fulfilled while designing flexure bearing viz. axial stiffness, radial stiffness and fatigue strength.

Design and analysis of flexure bearings

The design parameters for flexure bearings are geometry of profile, thickness of flexure bearing, diameter of flexure bearing, material and the total number of discs in stack. These parameters affects the flexure bearing characteristics. Out of this parameter, geometry of profile plays very important role in deciding axial and radial stiffness as well as fatigue strength. This research project work includes the development of new geometric profile which has better characteristics like lower axial stiffness and higher radial stiffness.

Modelling of Square, Pentagonal and Hexagonal arm flexure bearing

While designing spiral geometric profile, other parameters like spiral angle, number of starts need to be considered. As this parameters are increasing number of analysis needs to be done by using taguchi method also gets increases. This take more time to come on conclusion of analysis.

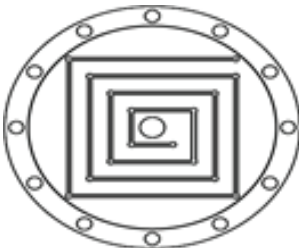

Fig. 2: a) Square arm

Fig. 2: b) Pentagonal arm

Fig. 2: c) Hexagonal arm

New geometric profiles were created in CATIA modelling software as shown in Figure 2. On the basis of slots created inside disc, names given to this profiles are square arm profile, pentagonal arm profile and hexagonal arm profile respectively. Thus bearings are called square arm flexure bearing, pentagonal arm flexure bearing and hexagonal arm flexure bearing. Square arm started at diameter of 10 mm that means inside square is the maximum area square that can fit in 10 mm diameter circle. This slot gets attached to the another square which has maximum area square that can fit in 20 mm diameter circle. This square arm again gets

increases by the step of 10 mm diameter circle till the decided diameter of flexure bearing. Same procedure is applied while creating pentagonal as well as hexagonal arm geometric profile. As per our shaft design inside hole is of 4.2 mm diameter and 12 clamping holes of 2.5 mm diameter were created in the geometry. Three parameters were chosen those are diameter of flexure disc, thickness of flexure disc and slot width. Three levels were taken for each of the parameter. Diameter levels were 50 mm, 60 mm and 70 mm. Thickness levels were 0.3 mm, 0.4 mm and 0.5 mm. Slot width levels were 0.4 mm, 0.5 mm and 0.6 mm. For every geometric profile as per L9 orthogonal array of taguchi method 9 geometries were developed. So, total 27 geometries were developed. Specifications of this 9 models are shown in Table 1.

Table 1. Different models using beryllium copper material (L9 orthogonal array)

Model No.	Diameter (mm)	Thickness (mm)	Slot width (mm)
Model 1	50	0.2	0.4
Model 2	50	0.3	0.5
Model 3	50	0.4	0.6
Model 4	60	0.2	0.5
Model 5	60	0.3	0.6
Model 6	60	0.4	0.4
Model 7	70	0.2	0.6
Model 8	70	0.3	0.4
Model 9	70	0.4	0.5

Analysis using finite element of Flexure Bearing

CATIA model of one of the hexagonal arm models is shown in Figure 3. Material chosen for the analysis was Beryllium copper which has young‟s modulus of 130000 Mpa. Poisson‟s ratio was taken as 0.3. The reason this material chosen for analysis is that we already have results of optimum model of spiral, linear and spline arm flexure bearing using beryllium copper as material. So that we can compare those results with our optimized geometric model.

Then meshing has been carried out in workbench. Workbench has used Hex20 element for the descretization. Model after descretization is also shown in Figure 4. The next step of analysis is solution. In this step boundary conditions and loading conditions needs to be applied. In our case clamping holes need to fixed and we have to give displacement in X direction and Y direction. As we are giving displacement in both directions it is called as biaxial loading. As we can see fixed support is shown by blue colour around the clamping holes. Displacement of 5 mm was given in X direction and 0.015 mm was given in Y direction. This displacements were applied at inner circle face.

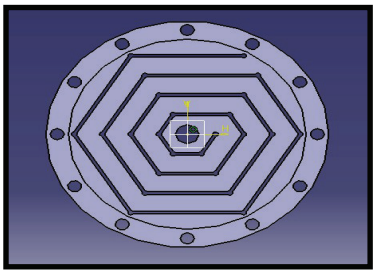

Fig. 3 CATIA model of Hexagonal arm

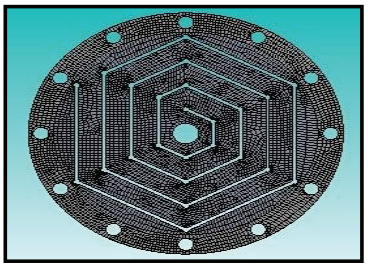

Fig. 4 Descretization

In last step of analysis result was find out. Model was checked for von-mises strains and von- mises stress. It is also checked for force in X direction and force in Y direction which will help us to find out axial stiffness and radial stiffness respectively. Model after deformation and von-mises stresses developed in model is shown in Figure 6 and Figure 7 respectively.

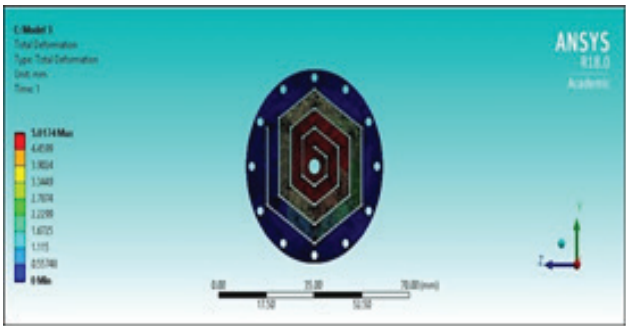

Fig. 6 Total Deformation

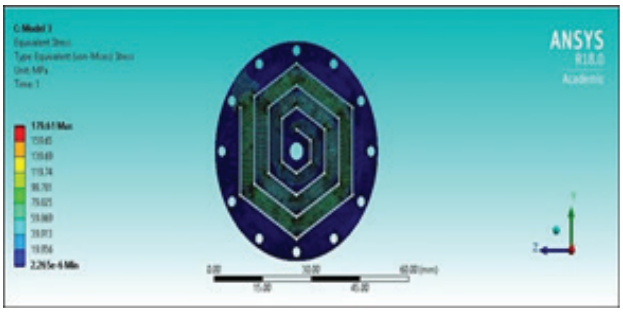

Fig. 7 Von-mises stresses developed in model

We can see in Figure 6 that maximum axial displacement is 5.0174 mm which is given as input before carrying out analysis. For this much of axial displacement we need to find out the forces developed in X direction and Y direction. This can be found out by using workbench Probe Force reaction option. From this axial displacement can be found out by dividing force reaction in X direction by 5mm as it is the displacement given in X direction. Radial displacement can be found out by dividing force in Y direction by 0.015 mm as it is displacement in Y direction.

RESULTS AND DISCUSSION

Same procedure as discussed it has been applied for every model of every geometry. This result are then tabulated. Table 2, Table 3 and Table 4 shows the obtained analysis results for square arm, pentagonal arm and hexagonal arm flexure bearing. This results need to be then analyzed to find out the optimized model. Optimized model is that model which has lower axial stiffness, high radial stiffness and maximum stress value less than the endurance limit of the material. We will compare this optimized model with the optimized model of other geometric profiles like spiral, linear and spline arm.

Table 2 Results of Square arm flexure bearing

Model No.	Von-mises strains *10^-6	Von-mises stress Mpa	Axial stiffness N/mm	Radial Stiffness N/mm
Model 1	1058.70	137.26	0.0130	4.2800
Model 2	1450.10	188.32	0.0418	5.9467
Model 3	1800.90	233.02	0.0947	7.3260
Model 4	489.19	63.30	0.0051	1.6200
Model 5	733.77	95.28	0.0164	2.2400
Model 6	970.90	125.57	0.0404	3.5133
Model 7	286.97	37.18	0.0024	0.7133
Model 8	447.65	58.06	0.0083	1.2733
Model 9	544.52	70.69	0.0187	1.5667

Table 3 Results of Pentagonal arm flexure bearing

Model No.	Von-mises strains *10^-6	Von-mises stress Mpa	Axial stiffness N/mm	Radial Stiffness N/mm
Model 1	904.36	117.21	0.0129	5.5011
Model 2	126.41	164.07	0.0419	7.7327
Model 3	1556.10	201.31	0.0952	9.6333
Model 4	425.97	55.084	0.0051	2.1217
Model 5	629.01	81.708	0.0165	2.9643
Model 6	855.48	111.13	0.0404	4.5427
Model 7	246.12	31.909	0.0024	0.9542
Model 8	385.49	49.995	0.0083	1.6531
Model 9	488.92	63.498	0.0189	2.0541

Table 4 Results of Hexagonal arm flexure bearing

Model No.	Von-mises strains *10^-6	Von-mises stress Mpa	Axial stiffness N/mm	Radial Stiffness N/mm
Model 1	812.33	105.28	0.0127	6.1867
Model 2	1127.90	146.45	0.0414	8.7507
Model 3	1384.20	179.61	0.0944	10.9700
Model 4	404.34	52.397	0.0511	2.4000
Model 5	567.75	73.72	0.0164	3.3733
Model 6	756.51	98.215	0.0400	5.1133
Model 7	217.76	28.185	0.0024	1.0867
Model 8	341.77	44.34	0.0082	1.8600
Model 9	420.18	54.5	0.0187	2.3267

From this results it can be found out that, Model no. 3 of Hexagonal flexure bearing has better characteristics as compared to other models. It has highest radial stiffness and stress values less than the endurance limit of beryllium copper. Some of the models have lower axial stiffness than this model but they have lower radial stiffness as well. Also axial stiffness model no. 3 of hexagonal bearing has sufficient axial stiffness. So optimized model is Model no. 3 of hexagonal bearing which has diameter of 50mm, thickness of 0.4 mm and slot width of 0.6 mm. This optimized model of flexure bearing needs to be compared with the optimized models of spiral, linear and spline arm flexure bearing.

We cannot compare values of axial stiffness and radial stiffness with the values of other geometrical profile models because every geometry has different dimensions and parameters. So for comparing this values normalized value method is used. In this method normalized axial stiffness, normalized radial stiffness and normalized von-mises strains are compared with respect to normalized axial displacement. Normalized axial stiffness can be calculated by using formula (Kz / ED) i.e. axial stiffness divided by young‟s modulus and diameter. Normalized radial stiffness can be calculated by using formula (Kr / ED) i.e. radial stiffness divided by young‟s modulus and diameter. Normalized axial displacement can be calculated by formula (z / D) i.e. axial displacement divided by diameter. By fixing the dimensions i.e. 50 mm diameter and 0.4 mm, results are found out for 1 mm to 5 mm of axial stiffness in the steps of 1 mm. This results are then compared with other geometric profile optimized models.

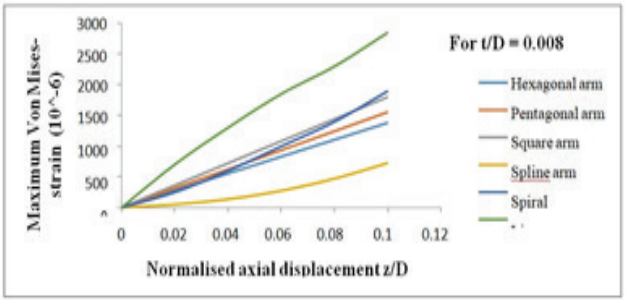

Fig. 9 Axial stiffness characteristics

Figure 8 shows the graphs of maximum Von-mises strain characteristics for different geometric profile. It shows that Von-mises strain values are less for spline arm flexure bearing and for linear flexure bearing it is highest. It can also be seen that as we go on increasing the sides of flexure bearing geometry i.e. from square to hexagon Von-mises strains decreases.

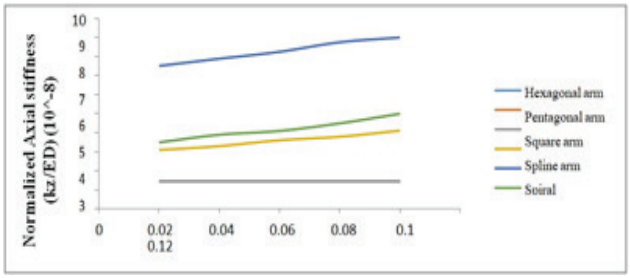

Fig. 10 Radial stiffness characteristics

Figure 10 shows the graphs of radial stiffness characteristics for different geometric profiles. It shows that normalized radial stiffness for hexagonal arm flexure bearing is highest while it is lowest for spline arm flexure bearing. It can be seen that as we go on decreasing the sides of geometric profile radial stiffness decreases. From this graphs we can say that hexagonal bearing has better characteristics as compared to other geometric profiles. Material used for above analysis was Beryllium copper but it has very high cost. So on the basis of properties and cost, stainless steel 310 is decided as material for analysis and manufacturing. As we are modifying the compressor, as per the previous design 50 mm is fixed diameter for flexure bearing. So again analysis has been carried out by taking stainless steel as material, fixed 50 mm diameter. In this analysis three parameters were taken. These parameters are geometry, thickness and slot width. For this also L9 orthogonal array was taken. This L9 orthogonal array is shown in Table 5.

Table 5. Different models using stainless steel as material (L9 orthogonal array)

Model No.	Geometry	Thickness (mm)	Slot width (mm)
Model 1	Hexagonal arm	0.2	0.4
Model 2	Hexagonal arm	0.3	0.5
Model 3	Hexagonal arm	0.4	0.6
Model 4	Pentagonal arm	0.2	0.5
Model 5	Pentagonal arm	0.3	0.6
Model 6	Pentagonal arm	0.4	0.4
Model 7	Square arm	0.2	0.6
Model 8	Square arm	0.3	0.4
Model 9	Square arm	0.4	0.5

Table 6 Results of models using stainless steel as material

Model No.	Von-mises strains* 10^-6	Von-mises stress Mpa	Axial stiffness N/mm	Radial Stiffness N/mm
Model 1	504.07	96.41	0.0192	9.2333
Model 2	679.65	130.3	0.0626	13.0467
Model 3	776.95	148.65	0.1429	16.3467
Model 4	522.21	100.01	0.0190	7.6867
Model 5	651.99	125.07	0.0618	10.7667
Model 6	964.55	184.59	0.1511	16.3800
Model 7	621.74	117.59	0.0187	5.4467
Model 8	847.51	162.03	0.0650	9.5533
Model 9	1129.70	216.06	0.1475	11.8067

This all models were also analyzed by using the procedure already discussed. Only difference is that while selecting material stainless steel 310 was selected from library of workbench. Stainless steel used is of grade 304 having young‟s modulus of 190000 Mpa. Poisson‟s ratio was taken as 0.3. Results of this models are shown in table 6. From this results we can found out that, here also Model no. 3 has shown good characteristics. Radial stiffness increases because of change in material. Axial stiffness also gets increases but percentage increase is only 11 % approximately. So finalized model for manufacturing has dimensions as follows:

- Geometry - Hexagonal arm
- Diameter - 50 mm
- Thickness - 0.4 mm
- Slot width - 0.6 mm
- Material - Stainless steel

The manufacturing the flexure bearing is done by using Photochemical Machining as shown below:

Fig. 11 Manufactured Flexure bearing discs

CONCLUSION

The systematic optimization of flexure bearings for miniature moving magnet compressors in pulse tube cryocoolers, utilizing Finite Element Analysis (FEA) and the Taguchi method with an L9 orthogonal array, has demonstrated significant advancements. Through rigorous evaluation of geometric configurations and material choices—including the transition from costly Beryllium copper to cost-effective stainless steel 310—the study confirms the development of a hexagonal arm flexure bearing for achieving superior axial and radial stiffness. This optimized design approach not only enhances the performance and reliability of flexure bearings but also underscores its pivotal role in advancing precision engineering for cryogenic applications.

REFERENCES

1 Patel, R., Smith, J., and Kumar, S. (2018), “The use of clearance seals in linearly driven miniature cryocoolers, Journal of Precision Engineering, 45(3), pp. 112-123.

2. Singh, A., Rao, P., and Mehta, K. (2017), “Dynamic stability of flexure-supported systems in linear electromagnetic drives,” International Journal of Cryogenic Engineering, 52(2), pp. 89-98.

3. Zhang, Z., Cheng, K.W.E., and Xue, X.D. (2013), “Study on the performance and control of linear compressor for household refrigerators”, IEEE Xplore.

4. Kumar, R., and Sharma, V. (2020), “Material selection for flexure bearings in cryogenic applications: Evaluating stainless steel 310,” Materials Science and Engineering, 112(4), pp. 55-64.

5. Lee, J., Park, S., and Kim, T. (2021), “Optimization of hexagonal arm flexure bearings for cryogenic cooling systems,” Journal of Cryogenic Engineering, 60(1), pp. 10-20.

6. Khot, M. and Gawali, B. (2015), “Finite element analysis and optimization of flexure bearing for linear motor compressor”, Physics Procedia, Vol. 67, pp. 379-385..

7. Abdalla, I.I., Ibrahim, T. and Nor, N.B.M. (2016), “Development and optimization of a moving-magnet tubular linear permanent magnet motor for use in a reciprocating compressor of household refrigerators”,

International Journal of Electrical Power & Energy Systems, Vol. 77, pp. 263-270.

8. Wang, X., Dai, W., Zhu, J., Chen, S., Li, H. and Luo, E. (2015), "Design of a two-stage high-capacity Stirling cryocooler operating below 30K", Physics Procedia, Vol. 67, pp. 518-523.

9. Dang, H. (2015), "Development of high performance moving-coil linear compressor for space Stirling-type pulse tube cryocoolers", Cryogenics, Vol. 68, pp. 1-8.

10. Teng, F. and Haitao, Y. (2013), "The design of a moving-magnet linear oscillating motor for linear compressors", Applied Mechanics and Materials, Vols. 416-417, pp. 433-438.

11. Chen, X. P., Sun, H., Nie, X. L., & Gan, Z. H. (2016). Overview of micro-miniature Stirling cryocoolers for high temperature applications. In Cryocoolers 19, International Cryocooler Conference, Boulder, CO.

Stir Casting Setup Designing for Casting Parameters Optimization to develop Mg-HAP Biodegradable MMCs

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ABSTRACT

Orthopedic implants can be made using magnesium and an alloy containing it. In actuality, their mechanical qualities are similar to those of real bone, and they possess full biocompatibility. Also, once the surgical site has fully healed, they don't need to be removed because of their biodegradable qualities, which might reduce the need for further procedures. On the other hand, an overabundance of magnesium can lead to internal corrosion and can impair bone repair. One method to lower the rate of corrosion and enhance the mechanical properties of magnesium is to create magnesium matrix composites. In order to create magnesium-based hydroxyapatite metal matrix biodegradable composites, a special stir casting machine configuration was created for this investigation. A crucible lid for stir casting machine furnace has been designed with provisions for argon gas supply, reinforcement supply, and placing stirrer without removing the lid throughout the entire fabrication process in order to achieve the goal of preventing magnesium oxidation and producing biodegradable metal matrix composite with the aim of improving the mechanical, metallurgical, microstructural, as well as the wear resisting properties. This means that in addition to being employed in several other disciplines, the biodegradable composites created using the stir casting technology may find utility in the biomedical industry.

KEYWORDS: *Metal matrix composites, Magnesium (Mg) Hydroxyapatite (HAP) metal matrix composites, Biodegradable MMCs, Stir casting setup, Crucible lid, Argon gas.*

INTRODUCTION

Metal Matrix Composites (MMCs)

Because of all the biomedical and industrial applications that metal matrix composites (MMCs) may be used for, MMCs are becoming more and more popular. MMCs are highly sought after because to their outstanding performance, straightforward design, and affordable production costs. Compared to their unreinforced monolithic competitors, MMCs are recognized for offering superior mechanical, thermal, and wear resistance properties. For diverse causes, a number of MMCs with particular properties have been created [5–12]. The Al-based ones are just one type; there are others that are based on Mg, Ni, Ti, Cu, and Fe. Al, Mg, Ti, Cu, and Fe make up the majority of the volume fraction in these MMCs, making up over 90% of the matrix components. Encouraging elements are the main means of enhancing MMC features and utilization. MMCs influence the features more than other materials even if they have a significantly less amount of reinforcing components. Reinforcing components include things like whiskers, fibers, and particles. A summary of the many kinds of useful fibers and particles is provided in the table. [1]

Table 1. Components of MMCs

Metal Matrix	Reinforcement		
	Whiskers	Fibers	Particulates
Aluminium (Al)	Graphite	Jute Fiber	Sic

Magnesium (Mg)	Cellulose	Keylar Fiber	Al_2o_3
Nickel (Ni)		Carbon Fiber	Graphene
Titanium (Ti)			Carbon Nanotubes
Copper (Cu)			
Iron (Fe)			

The most prevalent metal matrix composite phase in biomaterials is titanium [13]. Magnanimously strong and resistant to corrosion, titanium is a fantastic non-ferrous metal [14, 15]. Ti alloys and titanium have become widely employed in dental implants and orthopedics due to their exceptional strength, biocompatibility, and fracture toughness [16, 17]. Since titanium alloys have a high coefficient of friction, wear particles may be released into the circulation and cause titanium alloy implants to fail [18, 19]. Comparing the density, elastic modulus, and yield strength of magnesium implants with those of other metallic implants, bone tissue is more comparable [20].

Magnesium Metal Matrix Composites (Mg MMCs)

Patients recover more rapidly and are less likely to require repeat surgery as a result of the magnesium magnesium metal microneedles' low weight, biodegradability, and bioactivity. Mg MMCs are a better option than Ti and Al because of their elastic modulus, which is similar to that of the human body. Mg is not reactive, in contrast to Ti and Al, therefore the body helps with its absorption and dissolution [21, 22]. In contrast, pure magnesium (135 MPa) possesses low tensile strength, ductility, and hardness. Magnesium reinforcements are needed to enhance properties and meet specifications for a wide range of uses. Reinforcement may be derived from metal, ceramic, composite, and polymer materials. However, the processing method, kind, and quantity of reinforcement (the mechanism of reinforcement), as well as the proper reinforcing parameter, all affect the growth of mechanical qualities [23]. The processes that are employed to construct the reinforcing mechanism include powder metallurgy, additive manufacturing, stir casting, liquid infiltration, and semi-powder metallurgy. Controlling the porosity of the composite may be significantly impacted by the amount of reinforcing employed. High wet ability and biocompatibility composites are provided by the various kinds of reinforcement [22].

Magnesium–Hydroxyapatite Metal Matrix Composites (Mg- HAP MMCs)

Acknowledged for its remarkable biocompatibility and bioactivity, as well as its restricted solubility in biological contexts, hydroxyapatite (HAP) is a naturally occurring calcium apatite variation with the chemical formula Ca5(PO4)3(OH). Because they are chemically and physically similar, the minerals present in teeth and bone help to clarify this. The applications that can be employed with the HAP are limited by its modest weight bearing capacity. In magnesium-based MMCs meant for use as biomaterials, HAP particles can be added as reinforcements. A variety of implants' mechanical and physical characteristics are depicted. HAP has properties similar to those of real bone, including greater fracture toughness and compressive yield strength. The biocompatible magnesium matrix should ideally be reinforced with a small amount of HAP in order to obtain the best possible properties. [3]

Table 2. Application of Magnesium Metal Matrix Composites

Sr. No.	Industry	Applications
1.	Biomedical	Implants for the joints, Tibial components for prosthetic knees, plates of bone, screw-in bones, Femoral hips, cups for acetabulum
2.	Aerospace	transmission mechanisms for helicopters, a jet engine's fan frame surface controls, elements of structure, fringe flaps, Spacecrafts, Missiles
3.	Hydrogen storage	Solid-state hydrogen storage
4.	Electronics	Mobile phones, smart phones, and radar, Computers, TVs
5.	Automotive	Transmission cases Crankcases, engine blocks, supported by radiators, Chassis, Interiors, the interiors of doors

Processing challenges

Problems that affect the fabrication of magnesium matrix composites include appropriate processing

parameter settings, a challenging fabrication process, and secondary deformations in the fabricated composites [5,34]. Using an inert gas (argon) during the procedure will lessen the chance of oxidation. The picture graphically represents the initial modifications made to MMCs.

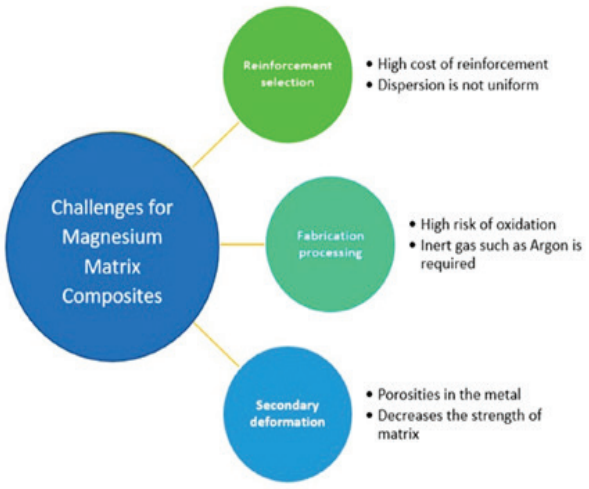


Fig. 1. Challenges for Mg Metal Matrix Composites [1]

Mg MMCs Development Processes

The metal matrix composite is primarily manufactured using three different methods: liquid metallurgy, powder metallurgy, and solid-state processing. Magnesium matrix composites are, however, typically produced using just a few number of processes, which fall into the categories that are listed below. [1]

Processing in a liquid state

For producing complicated shapes with high dispersion and interfacial adhesion, liquid-state processing is a great technique. Improved mechanical properties are the consequence of improved bonding and uniform reinforcement distribution. Reference [26]. These three liquid metallurgy techniques are the most often used: centrifugal casting, squeezing casting, and stirring casting. Making magnesium matrix composites is most commonly done via stir casting. [1]

Processing of Stir Casting

The method most frequently employed to create MMCs in liquid form is stir casting. Reinforcing particles in a molten metal matrix can be mechanically mixed more easily using stir casting [38–41]. The graphic shows a schematic of the stir casting procedure.

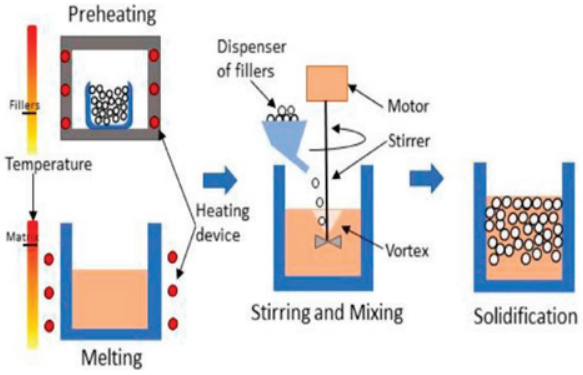


Fig. 2. Stir Casting process [1]

Table 3. Contrasting the different magnesium matrix composite production techniques

Sr. No.	Components	Process Key	Findings	Reference
1.	Mg + 5 wt.% SiC and 5 wt.% Al2O3	Friction stir processing	Tensile strength, hardness, and wear resistance of the material were at their highest when the rotating speed reached 540 rpm. 10 mm per minute for the linear speed.	[32]
2.	AZ91D + 5, 10, 15 and 20 vol.% Ti2AlC	Stir casting	Yield strength, hardness, compressive strength, and Young's modulus all increased with increasing material percentage. However, 10% Ti2AlC percentage was found, making Ti2AlC the best UTS.	[1]
3.	AZ91D + 5, 10, 15, 20 vol.% SiC	Ultrasound-assisted stir casting	It has been shown that ultrasonic treatment works best when given a 20-minute timeframe. The liquid's silicate crystal particle dispersion was enhanced by a 5-minute swirl. The highest UTS, which was found to be 15% concentration.	[1]

4.	(Mg powder + 2 wt.% CNT)	Powder metallurgy	The Young's modulus of the CNTs with a Mg-2 weight percentage was 9% higher than that of Mg and unreinforced CNTs. Measuring results are verified by that resonating confirmation. It has comparable strength to magnesium without reinforcements in terms of durability, tensile stress after fracture, and yield strength.	[9]
5.	AZ31 + Ni-CNT concentrations (0.5, 1, 1.5 wt.%)	Hot-press sintering	Ni-coated CNTs were evenly dispersed throughout. In AZ31/1% Ni-CNT composite, the optimum tensile and microhardness properties of the material were discovered.	[35]

The impacts of the reinforcing element in magnesium matrix composites

The figure demonstrates how a significant impact of reinforcement in magnesium is felt on the basic properties. [1]

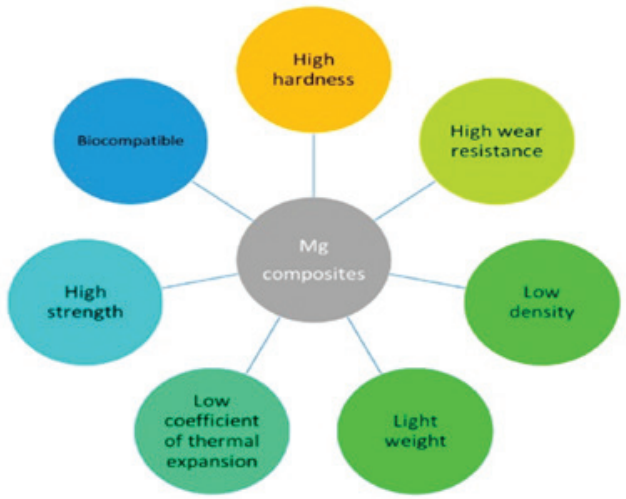


Fig. 3. Properties of Magnesium Matrix Composite [1]

Stir Casting

Vortices that combine the reinforcing and matrix material are created during the stirring casting process by a mechanical stirrer. Since it is low-cost, easily scalable, basically net-shaped, and manageable in terms of composite structure, it is a great method for producing metal matrix composites.

Stir Casting Machine the setup and its elements are as follows

The parts of the stir casting machine shown in Figure include a mechanical stirrer, reinforcement feeding, and a furnace. Heating and melting the materials occurs in the furnace. The bottom poring furnace is a better option for stir casting as expeditious poring is necessary to prevent solid particles from sinking to the bottom of the crucible after the mixed slurry has been rotated. The mechanical stirrer generates a vortex that facilitates the addition of reinforcing elements to the melt mixture. Two components make up a stirrer: a stirring rod and an impeller blade. An impeller can have different designs and counts of blades. Less power is used when axial flow pattern in the crucible is produced by utilizing flat blades with three numbers. The stirrer's motors are powered by different motor speeds, and each motor is connected to a regulator that controls the stirrer's spinning speed. In order to feed the reinforcing powder into the melting metal, the feeder—which is connected to the furnace—is utilized. Utilize a lost-wax, sand cast, or permanent mold to accept the mixed slurry. [4]

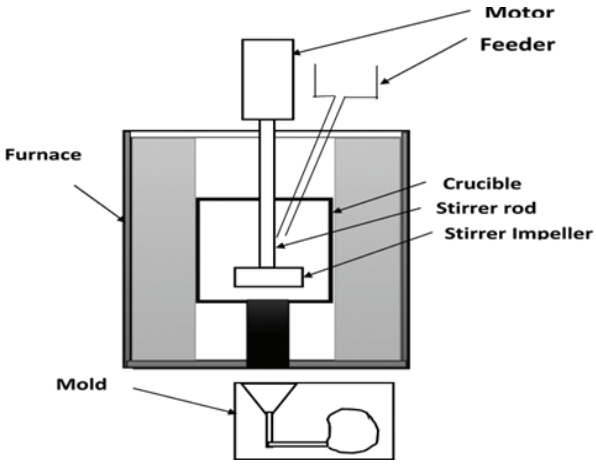


Fig. 4. Schematic of Stir Casting setup [4]

Process of Stir Casting

The various stages of the stir casting process are shown in Figure.

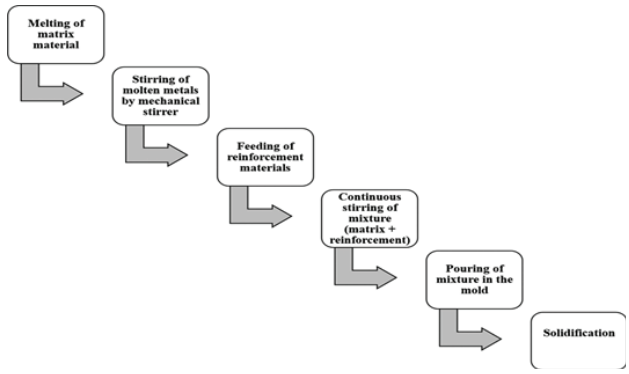


Fig. 5. Process of Stir Casting [4]

Stir Casting Techniques (SCTs) for Processing MMSFs are Classified

Compo casting (CC), modified stir casting (MSC), conventional stir casting (CSC), and disintegrating melt deposition (DMD) are the four fundamental processes that make up the SC family, according to the data examined (Figure).

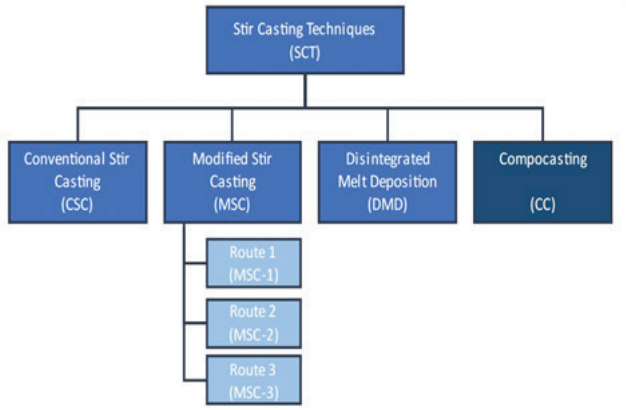


Fig. 6. Classification of Stir Casting Techniques (SCTs) for processing MMSFs [2]

EXPERIMENTAL METHODOLOGY

Designing Layout for Stir Casting Machine Setup with Argon Gas Shielding Arrangement shown as following

A furnace, a mechanical stirrer, and a reinforcement feeder make up the stir casting setup design arrangement seen in Figure. Heat and melting of the materials are done in a furnace. A crucible is what makes up the furnace, and it is positioned within. When the reinforcing elements are introduced to the melt, a vortex is created by the mechanical stirrer, which facilitates mixing. The stirrer is made up of the impeller blades and stirring rod. Three digits on a flat blade were used because they utilize less power and create an axial flow pattern in the crucible. The motor's regulator controls the stirrer's rotation speed when it is connected to variable speed motors. The feeder is used to add reinforcing powder to the melt and is connected to the furnace. A permanent mold was used to pour the combined slurry. The continuous supply of argon gas was ensured by the use of an argon gas cylinder to prevent magnesium oxidation.

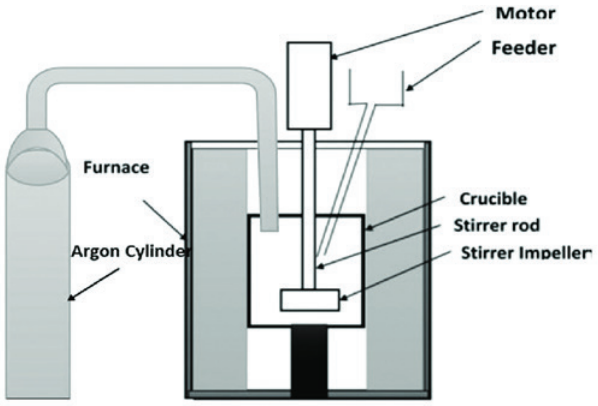
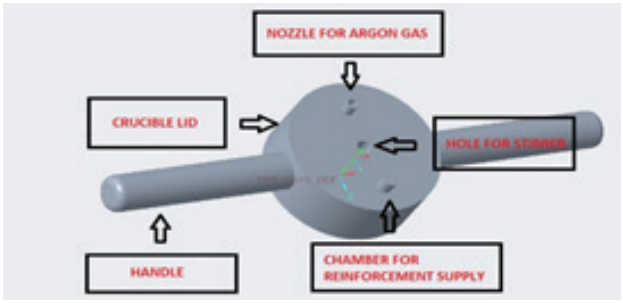


Fig. 7. Designing Layout for Stir Casting Machine Setup with Argon Gas Shielding Arrangement

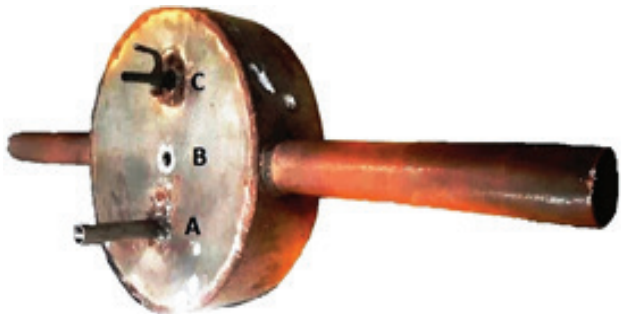
Designing Layout of Crucible Lid for Argon Gas shielding arrangement

As previously mentioned, Mg-Hap composites cannot be produced using a stir casting machine configuration without argon gas shielding equipment. An circle with a diameter of 266.7 mm was cut out of mild steel sheet to achieve this. After that, the circular plate was trimmed to the desired shape of a lid and soldered to a strip that was 76.2 mm tall. It must be securely positioned above the crucible's opening mouth in the stir casting apparatus. With two gripping handles measuring 254 mm in length and 50.8 mm in diameter, the crucible lid cover is equipped. Throughout the production process, handling the crucible lid will be simpler with this holding configuration. The upper surface of the crucible lid has three holes drilled into it: an 8 mm diameter hole (A) for welding the reinforcement supply chamber, an 8 mm diameter hole (C) for securing the argon gas supply nozzle, and a center hole (B) with a diameter of 12 mm for the stirrer to enter the crucible and stir the melting

metal. The graphic illustrates the crucible lid's smart design strategy for argon gas dispersion.



a



b

Fig. 8. (a) Designing of Crucible Lid for Argon Gas Supply; (b) Designed Crucible Lid for Argon Gas Supply

Fabrication Process of Magnesium Hydroxyapatite Metal Matrix Composite by Stir Casting machine setup with designed argon gas shielding arrangement (Crucible Lid)

The crucible, which was located in the electric furnace (A) of the stir casting machine configuration shown in the figure, needed to have the prescribed crucible cover placed over its opening mouth in order to produce the magnesium hydroxyapatite metal matrix composite. Through a specifically designed nozzle fastened to the upper side of the crucible lid, argon gas was supplied to the crucible from an argon gas cylinder. In order to provide the stirring motion required to evenly mix the reinforcement in the molten metal, the three-bladed impeller electric stirrer (D) was placed into the crucible through the designated aperture on the top side of the crucible lid. Strengthening the molten metal within the crucible was the chamber attached to the top of the lid. On top of the crucible lid is a nozzle that feeds argon gas into the crucible from the argon gas cylinder (B). Attached to the stir casting machine setup is a control device (C) that regulates the temperature of the electric furnace. Below is a schematic of the previously mentioned configuration.

a

b

Fig. 9. (a) Stir casting machine setup with designed argon gas shielding arrangement (Crucible Lid); (b) Stir casting machine setup with molten metal inside the Crucible

RESULTS AND DISCUSSIONS

Designing Parameters of Crucible Lid

Mild steel was the material utilized for the design. To create a lid-like form that would allow it to be securely fastened over the crucible, a mild steel sheet was cut into a circle with a diameter of 266.7 mm. A rectangular strip measuring 266.7 mm in length and 76.2 mm in height was then welded to the circular plate. Three holes were drilled in the lid's top, correspondingly measuring 8 mm for the reinforcement supply chamber (A), 12 mm for the stirrer (B), and 8 mm for the argon gas supply nozzle (C). Handles measuring 254 mm in length and 50.8 mm in diameter have been included on either side of the crucible lid to facilitate effortless handling. Throughout the casting process, an argon gas atmosphere is provided to prevent magnesium from totally oxidizing, and the crucible lid was designed and built to fit the crucible correctly inside the furnace. This prevents ambient oxygen from entering the crucible.

In this method, better mechanical and microstructural qualities will be achieved in the resulting magnesium-based hydroxyapatite metal matrix biodegradable composite, making it appropriate for use in biology. The processing parameters of the stir casting machine were improved in order to create magnesium hydroxyapatite metal matrix composites that are biodegradable and suitable for use in the biomedical industries.

Table 4. Specifications of Designed Crucible Lid

Sr. No.	Measurement Parts	Units
1.	Material	Mild Steel
2.	Diameter of Lid	266.7mm
3.	Height of Lid Side	76.2mm
4.	Diameter of hole of Chamber for Reinforcement Supply (A)	8mm
5.	Diameter of hole for Stirrer (B)	12mm
6.	Diameter of hole of Nozzle for Argon gas Supply (C)	8mm
7.	Length of Holding Handle (each side)	254mm
8.	Diameter of Holding Handle (each side)	50.8mm

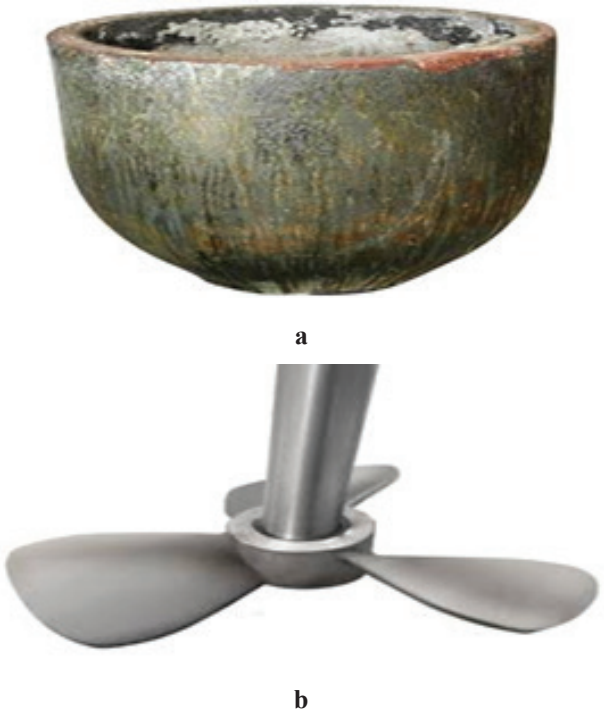
Specifications of Crucible and Stirrer with Three Blade Impeller

A ceramic crucible has been utilized for casting in order to optimize the process. In the stir casting machine configuration, a furnace with a 2 kg melting capacity and dimensions of 228.6 mm in diameter and 203.2 mm in depth has been chosen to melt magnesium matrix with hydroxyapatite reinforcing material.

When creating the magnesium hydroxyapatite metal matrix composite, a three-bladed stirrer was used in the crucible to evenly mix the reinforcement with the molten metal.

Table 5. Specifications of Crucible

Sr. No.	Measurement Parts	Units
1.	Material	Ceramic
2.	Melting Capacity	2Kg
3.	Diameter	228.6mm
4.	Depth	203.2mm



a

b

Fig 10. (a) Ceramic Crucible; (b) Stirrer with Three Blade Impeller

CONCLUSION

There have been earlier mentions in the literature of many magnesium matrix composite fabrication processes. The most crucial processes include hot-press sintering, powder metallurgy, friction stir processing, stir casting, and ultrasound-assisted stir casting. For the production of magnesium-based hydroxyapatite metal matrix biodegradable composites, stir casting is the most economical and efficient technique. According to the literature, argon gas should be present during the whole casting process in order to produce magnesium matrix composites and prevent magnesium from oxidizing while it is molten. In order to produce magnesium-based hydroxyapatite metal matrix biodegradable composites with improved mechanical, microstructural, and metallurgical properties for use in biomedical applications, the most urgent concern is the design and development of a stir casting machine setup with an argon gas shielding arrangement for optimizing casting parameters. In order to satisfy those needs, a mild steel

crucible lid was created. It can supply argon gas to the molten magnesium matrix and feed hydroxyapatite reinforcement materials to it without having to be removed during manufacturing. It can also create an inert environment surrounding the molten magnesium metal by completely enclosing it in argon gas to prevent oxidation during the fabrication process. Because of its snug fit over the crucible opening, the crucible lid is meant to provide an inert atmosphere inside. In order to facilitate the stirrer's proper functioning and the proper mixing of reinforcement inside the molten magnesium metal, a hole is also bored so that the stirrer may pass through without requiring the removal of the crucible lid. Three blade impellers were used in the casting process in addition to this specific crucible. The characteristics of the casting process have been enhanced via the design and development of the Crucible lid. Magnesium oxidation during industrial processes might potentially be solved at a practical pace. The creation of magnesium hydroxyapatite metal matrix composite for use in the biomedical and other industries might be made more efficiently and economically by improving manufacturing processes in this way.

REFERENCES

1. Gurmeet Singh Arora, Kuldeep Kumar Saxena, Kahtan A. Mohammed, Chander Prakash and Saurav Dixit, (2022), ''Manufacturing Techniques for Mg-Based Metal Matrix Composite with Different Reinforcements'', MDPI, Crystals 2022, 12, 945. https:// doi.org/10.3390/cryst12070945.

2. Sánchez de la Muela, A.M.; Duarte, J.; Santos Baptista, J.; García Cambronero, L.E.; Ruiz-Román, J.M.; Elorza, F.J., (2022), ''Stir Casting Routes for Processing Metal Matrix Syntactic Foams: A Scoping Review'', MDPI, Processes 2022, 10, 478. https://doi.org/ 10.3390/pr10030478.

3. MeysamHaghshenas, (2017),`` Mechanical Characteristics Of Biodegradable Magnesium Matrix Composites: A Review'', Journal Of Magnesium And Alloys 5 (2017) 189–201.

4. Mohit Kumar Sahu and Raj Kumar Sahu, (2018), ''Fabrication of Aluminum Matrix Composites by Stir Casting Technique and Stirring Process Parameter Optimization'',http://dx.doi.org/10.5772/intechopen.73485.

5. Nai, M.H.; Wei, J.; Gupta, M. Interface tailoring to enhance mechanical properties of carbon nanotube reinforced magnesium composites. Mater. Des. 2014, 60, 490–495.

6. Habibi, M.K.; Paramsothy, M.; Hamouda, A.M.S.; Gupta, M. Enhanced compressive response of hybrid Mg–CNT nano-composites. J. Mater. Sci. 2011, 46, 4588–4597.

7. Li, C.;Wang, X.; Liu,W.; Shi, H.; Ding, C.; Hu, X.; Zheng, M.;Wu, K. Effect of solidification on microstructures and mechanical properties of carbon nanotubes reinforced magnesium matrix composite. Mater. Des. 2014, 58, 204–208.

8. Zou, N.; Li, Q. Compressive mechanical property of porous magnesium composites reinforced by carbon nanotubes. J. Mater. Sci. 2016, 51, 5232–5239.

9. Carreño-Morelli, E.; Yang, J.; Couteau, E.; Hernadi, K.; Seo, J.W.; Bonjour, C.; Schaller, R. Carbon nanotube/ magnesium composites. Phys. Status Solidi (A) 2004, 201, R53–R55.

10. Sabetghadam-Isfahani, A.; Abbasi, M.; Sharifi, S.; Fattahi, M.; Amirkhanlou, S. Microstructure and mechanical properties of carbon nanotubes/AZ31 magnesium composite gas tungsten arc welding filler rods fabricated by powder metallurgy. Diam. Relat. Mater. 2016, 69, 160–165.

11. Li, C.;Wang, X.; Liu,W.;Wu, K.; Shi, H.; Ding, C.; Hu, X.; Zheng, M. Microstructure and strengthening mechanism of carbon nanotubes reinforced magnesium matrix composite. Mater. Sci. Eng. A 2014, 597, 264–269.

12. Yuan, X.; Zhu, H.; Ji, H.; Zhang, Y. Effect of CNT contents on the microstructure and properties of CNT/ TiMg composites. Materials. 2019, 12, 1620.

13. Abazari, S.; Shamsipur, A.; Bakhsheshi-Rad, H.R.; Ismail, A.F.; Sharif, S.; Razzaghi, M.; Ramakrishna, S.; Berto, F. Carbon nanotubes (CNTs)-reinforced magnesium-based matrix composites: A comprehensive review. Materials 2020, 13, 4421.

14. Prakash, C.; Singh, S.; Basak, A.; Krolczyk, G.; Pramanik, A.; Lamberti, L.; Pruncu, C.I. Processing of Ti50Nb50□xHAx composites by rapid microwave sintering technique for biomedical applications. J. Mater. Res. Technol. 2019, 9, 242–252.

15. Prakash, C.; Singh, S.; Pramanik, A.; Basak, A.; Królczyk, G.; Bogdan-Chudy, M.; Wu, Y.L.; Zheng,

H.Y. Experi-mental investigation into nano-finishing of _-TNTZ alloy using magnetorheological fluid magnetic abrasive finishing process for orthopedic applications. J. Mater. Res. Technol. 2021, 11, 600–617.

16. Singh, S.; Prakash, C. Effect of cryogenic treatment on the microstructure, mechanical properties and finishability of -TNTZ alloy for orthopedic applications. Mater. Lett. 2020, 278, 128461.
17. Singh, H.; Prakash, C.; Singh, S. Plasma spray deposition of HA-TiO2 on _-phase Ti-35Nb-7Ta-5Zr alloy for hip stem: Characterization of bio-mechanical properties, wettability, and wear resistance. J. Bionic Eng. 2020, 17, 1029–1044.
18. Prakash, C.; Singh, S.; Ramakrishna, S.; Królczyk, G.; Le, C.H. Microwave sintering of porous Ti–Nb-HA compo-site with high strength and enhanced bioactivity for implant applications. J. Alloys Compd. 2020, 824, 153774.
19. Pradhan, S.; Singh, S.; Prakash, C.; Królczyk, G.; Pramanik, A.; Pruncu, C.I. Investigation of machining characteris-tics of hard-to-machine Ti-6Al-4V-ELI alloy for biomedical applications. J. Mater. Res. Technol. 2019, 8, 4849–4862.
20. Prakash, C.; Singh, S.; Ramakrishna, S. Characterization of indigenously coated biodegradable magnesium alloy primed through novel additive manufacturing assisted investment casting. Mater. Lett. 2020, 275, 128137.
21. Singh, G.; Singh, S.; Prakash, C.; Ramakrishna, S. On investigating the soda-lime shot blasting of AZ31 alloy: Ef-fects on surface roughness, material removal rate, corrosion resistance, and bioactivity. J. Magnes. Alloy. 2021, 9, 1272–1284.
22. Prakash, C.; Singh, S.; Farina, I.; Fraternali, F.; Feo, L. Physical-mechanical characterization of biodegradable Mg-3Si-HA composites. PSU Res. Rev. 2018, 2, 152–174.
23. Mohan, N.; Senthil, P.; Vinodh, S.; Jayanth, N. A review on composite materials and process parameters optimisation for the fused deposition modelling process. Virtual Phys. Prototyp. 2017, 12, 47–59.
24. Xiao, J.; Shu, D.W.; Wang, X. Effect of strain rate and temperature on the mechanical behavior of magnesium nanocomposites. Int. J. Mech. Sci. 2014, 89, 381–390.
25. Zengin, H.; Turen, Y. Effect of La content and extrusion temperature on microstructure, texture and mechanical properties of Mg-Zn-Zr magnesium alloy. Mater. Chem. Phys. 2018, 214, 421–430.
26 Shen, J.; Yin,W.; Kondoh, K.; Jones, T.L.; Kecskes, L.J.; Yarmolenko, S.N.;Wei, Q. Mechanical behavior of a lantha-num-doped magnesium alloy at different strain rates. Mater. Sci. Eng. A 2015, 626, 108–121.
27. Malik, A.; Chaudry, U.M.; Yan, T.; Long, J.; Li, C.; Wang, Y. Achieving higher dynamic me-chanical response by adjusting texture through twinning in a ZK61 Mg alloy. J. Alloys Compd. 2022, 902, 163755.
28. Rashad, M.; Pan, F.; Asif, M.; She, J.; Ullah, A. Improved mechanical proprieties of "magnesium based composites" with titanium–aluminum hybrids. J. Magnes. Alloy. 2015, 3, 1–9.
29. Aatthisugan, I.; Rose, A.R.; Jebadurai, D.S. Mechanical and wear behaviour of AZ91D magnesium matrix hybrid composite reinforced with boron carbide and graphite. J. Magnes. Alloy. 2017, 5, 20–25.
30. Xiang, S.;Wang, X.; Gupta, M.;Wu, K.; Hu, X.; Zheng, M. Graphene nanoplatelets induced heterogeneous bimodal structural magnesium matrix composites with enhanced mechanical properties. Sci. Rep. 2016, 6, 38824.
31. Malik, A.;Wang, Y.; Huanwu, C.; Nazeer, F.; Ahmed, B.; Khan, M.A.; Mingjun,W. Constitutive analysis, twinning, recrystallization, and crack in fine-grained ZK61 Mg alloy during high strain rate com-pression over a wide range of temperatures. Mater. Sci. Eng. A 2020, 771, 138649.
32. Arokiasamy, S.; Ronald, B.A. Experimental investigations on the enhancement of mechanical properties of magnesium-based hybrid metal matrix composites through friction stir processing. Int. J. Adv. Manuf. Technol. 2017, 93, 493–503.
33. Prakash, C.; Singh, S.; Gupta, M.K.; Mia, M.; Królczyk, G.; Khanna, N. Synthesis, characterization, corrosion re-sistance and in-vitro bioactivity behavior of biodegradable Mg–Zn–Mn–(Si–HA) composite for orthopaedic applica-tions. Materials 2018, 11, 1602.
34. Shang, Y.; Pistidda, C.; Gizer, G.; Klassen, T.; Dornheim, M. Mg-based materials for hydrogen storage. J. Magnes. Alloy. 2021, 9, 1837–1860.
35. Wu, L.; Wu, R.; Hou, L.; Zhang, J.; Sun, J.; Zhang, M. Microstructure and Mechanical Properties of CNT-Reinforced AZ31 Matrix Composites Prepared Using Hot-Press Sintering. J. Mater. Eng. Perform. 2017, 26, 5495–5500.

36. Mishra, M.; Prakash, C.; Shabadi, R.; Singh, S. Mechanical and microstructural characterization of magnesi-um/multi-walled carbon nanotubes composites fabricated via friction stir processing. In Advances in Materials Science and Engineering; Springer: Singapore, 2020; pp. 137–147.

37. Srichok, T.; Pitakaso, R.; Sethanan, K.; Sirirak, W.; Kwangmuang, P. Combined response surface method and modified differential evolution for parameter optimization of friction stir welding. Processes 2020, 8, 1080.

38. Dinaharan, I.; Zhang, S.; Chen, G.; Shi, Q. Titanium particulate reinforced AZ31 magnesium matrix composites with improved ductility prepared using friction stir processing. Mater. Sci. Eng. A 2019, 772, 138793.

39. Sajjadi, S.; Ezatpour, H.; Beygi, H. Microstructure and mechanical properties of Al–Al2O3 micro and nano composites fabricated by stir casting. Mater. Sci. Eng. A 2011, 528, 8765–8771.

40. Ezatpour, H.; Torabi-Parizi, M.; Sajjadi, S.A. Microstructure and mechanical properties of extruded Al/Al2O3 composites fabricated by stir-casting process. Trans. Nonferrous Met. Soc. China 2013, 23, 1262–1268.

41. Sajjadi, S.; Ezatpour, H.; Parizi, M.T. Comparison of microstructure and mechanical properties of A356 aluminum alloy/Al2O3 composites fabricated by stir and compo-casting processes. Mater. Des. 2012, 34, 106–111.

A Simplified Theoretical Model for Value Stream Mapping (VSM) Implementation in Small and Medium Enterprises (SMEs)

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ABSTRACT

Every organization, it might be a large organization or small and medium enterprises functions within some constraints which controls the whole operation of the organization. These constraints might be financial constraints, environmental constraints or constraint related to resources like man, machine or material. Considering the constraints of small and medium enterprises & studying these constraints in depth, the theoretical model for Value Stream Mapping implementation is proposed in this study. The focus is kept on designing it in simple way, so that all small and medium enterprises feel comfortable to implement it. Before developing a Value Stream Mapping model, a detailed study of constraints is required. To finalize these constraints and to formulate a model a short survey is carried out in small and medium enterprises in Kolhapur Industrial area. During the survey questionnaire is to given owners, managers and operators and a small interview is also taken to see awareness level in small and medium enterprises about Value Stream Mapping. The stages with which the Value Stream Mapping model could be implemented are Problem Identification ,Data Collection ,Calculation of time measures , Drawing current state map, Analyzing the current state map, Identification of possible solutions, Drawing future state map and finally Assessment of productivity.

KEYWORDS: *Lean manufacturing, Productivity, Value steam mapping, Small and medium enterprises.*

INTRODUCTION

Lean manufacturing is a philosophy focused on identifying and eliminating waste in production, including energy, time, motion, and resources. Tools like Just-in-Time (JIT), cellular manufacturing, and total productive maintenance are commonly used. Lean manufacturing systematically reduces waste through continuous improvement, aiming to lower costs and maintain competitiveness [1]. Value Stream Mapping (VSM) identifies all actions, both value-added and non-value-added, required to deliver a product from raw material to the customer. It considers material and information flow across the supply chain to identify and reduce waste, focusing on the broader picture rather than individual processes [2]. Crowe and Arisha [3] highlight that VSM effectively maps an organization's current and future lean activities, improving productivity and providing a realistic organizational view. Through simulation, they emphasized identifying value and non-value activities for better future-state maps. Manjunath et al. [4] demonstrated VSM's potential in lean manufacturing, showing a 38.2% reduction in lead time, 2.65% reduction in process time, and 48.3% reduction in inventory. Khalid et al. [5] found VSM critical in implementing lean principles to improve productivity. Hines and Rich [6] emphasized that VSM's focus on waste reduction, inspired by Toyota, extends lean practices to supply chains. Nishattusnim et al. [7] improved workflows by transitioning from a push to a pull system, reducing changeover times and work-in-progress inventory.

Belokar et al. [8] highlighted that lean production is an ongoing process, with VSM enabling the continuous elimination of waste, fostering a culture of improvement. Turkyilmaz et al. [9] identified non-value-added operations through VSM, stressing the need for operator involvement to ensure effective results. Seyed and Hariprasad [10] noted differences in applying VSM in manufacturing and product development due to the unique nature of product development activities. Verma and Sharma [11] found VSM effective in reducing waste by distinguishing value-added from non-value-added activities, while Rohani and Zahraee [12] showed its success in the color industry, where production lead time decreased from 8.5 to 6 days, and value-added time dropped from 68 to 37 minutes. Romero and Arce [13] promoted adapting VSM across environments to improve visibility and performance.

Kumar et al. [14] emphasized VSM's role in identifying inefficiencies, boosting productivity, and mapping current and future states for continuous improvement. Chaudhari et al. [15] linked VSM with tools like 5S and Kaizen to reduce operator motion by 27.1% and process time by 22.8 seconds, recommending Kanban for lead time and inventory control. Kannan Jayaraman [16] highlighted VSM's ability to provide a broader perspective, enabling prioritized improvements. From the literature, gaps emerge regarding VSM implementation in SMEs. Research tailored for SMEs can enhance productivity and overall effectiveness. This paper proposes a simplified eight-stage model for SMEs: problem identification, data collection, time calculation, current-state mapping, analysis, solution identification, future-state mapping, and productivity assessment. The approach emphasizes low-cost automation, minimal disruptions, and human-centric factors like operator fatigue, making VSM more practical for SMEs.

METHODOLOGY

The purpose of this investigation is to form a theoretical model of Value Stream Mapping for SMEs. This model will work as a benchmark to various manufacturing SMEs for implementation of VSM. Every organization, it might be a large organization or SME ,functions within some constraints which controls the whole operation of the organization. These constraints might be financial constraints, environmental constraints or constraint related to resources like man, machine or material. Before developing a VSM model, a detailed study of constraints is required. To finalize these constraints and to formulate a model a short survey is carried out in SMEs in Kolhapur Industrial area. During the survey questionnaire is given owners, managers and operators during this a small interview is also taken to see awareness level in SMEs about VSM. The questionaries' of survey is based on following important aspects of SMEs

Human Resource

1. Will you spare dedicated staff for quality improvement initiatives?

Options : Yes, Maybe, No

Expertise Level of Human Resources

2. What is the percentage of highly skilled expertise in your organization?

Options :Less than 10%, 10-30%, 30-70%, Above 70%

Decision Making

3. Are you agile in taking decisions in your business?

Options :Yes, No (Delayed decisions)

4. If "No," what are the reasons?

Options :Financial Burden, Market Uncertainties, Government Regulations, Competitive Market

5. Are managers' delegated authority to take decisions in emergency situations?

Options: Yes, Moderate, No

6. Are workers allowed to take decisions at the shop floor level?

Options: Yes, Moderate, No

Risk Factors

7. What are your major business risks?

Options :Resistance to Change, Product Variety, Product Volume, Peer Competition, Ever-changing Customer Requirements

Cost of Automation

8. What is your preferable level of automation?

Options :Low Cost, Medium Cost, High Cost

Availability of Funds

9. Do you follow fund allocation through budgets for quality improvement initiatives?

Options :Yes, No

Resistance to Change

10. What are the reasons for fear of change at the managerial level?

Options: Work Accountability, Fear to Upgrade, Fear of Failure, No Monetary Benefits

11. What are the reasons for fear of change amongst workers on the shop floor?

Options: Fear of Losing Job, Fear to Upgrade, Higher Working Hours, Low Monetary Benefits

Awareness Levels

12. What is your level of awareness about the following features?

- Quality: Low, Moderate, High

- Technology: Low, Moderate, High

- Finance: Low, Moderate, High

The survey highlights that SMEs often face challenges in sparing dedicated staff for quality improvement due to cost constraints and a preference for multi-skilled operators handling routine tasks. Most SMEs report less than 30% highly skilled workforce, which poses difficulties in implementing advanced tools like VSM. Decision-making agility is generally high among owners due to simpler organizational structures, but financial burdens and market uncertainties cause delays. Managers and workers typically lack authority to make shop floor decisions, concentrating decision-making power with owners. Resistance to change, especially from owners and workers, arises due to fear of job loss, higher workloads, and monetary concerns. SMEs prefer low-cost automation to control expenses, despite its potential productivity benefits. Fund allocation for quality improvement is limited, reflecting tight financial conditions and prioritization of loan repayments. Awareness levels of quality, technology, and finance vary significantly, with owners showing higher awareness compared to managers and workers. Overall, a lack of awareness, resistance to change, and financial constraints collectively hamper SME growth and quality improvement initiatives.

THEORETICAL MODEL FOR VALUE STREAM MAPPING (VSM) IMPLEMENTATION IN SMALL AND MEDIUM ENTERPRISES (SMES)

Based on the outcome of Survey the stages with which the VSM model could be implemented are as shown in Figure 1.

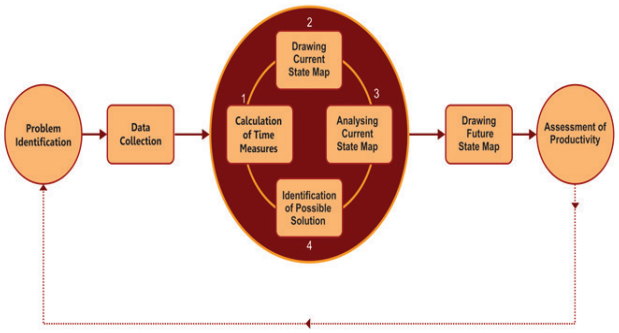

Fig. 1 Proposed VSM Theoretical Model

Problem Identification

The first and very important step in implementation of VSM is identifying the exact problem in current situation. The problem may be considered as the difference between actual situation and expected situation. This necessitates the formation of a team of experts. The number of people in the team may depend on availability of expert the human resource in the company. Care should be taken while forming the team that the person who is part of the team should have all knowledge about the products, processes and the overall functioning of the company. Also they should possess minimum required technical expertise to understand and respond speedily. It is desired that the person who will be able to take decision, should be the member of team. In case of SME Preferably the owner or the manager should be part of the team.

While identifying the problem it is important to consider the customer ratings. Also what are the actual expectations of the customer? The feedback of customer will also help in this case. In this process the customer demand also plays vital role. The customer demand are variable may be weekly, monthly or yearly basis. The

team may refer the past data available with company. The team will discuss about the current situation. The brainstorming session of the team members having experience about the products, customer & company will help to identify the problem precisely.

Data Collection

Data Collection is important process in case of all improvements initiatives or research. It is the way of gathering the desired information of variables required in a systematic way. If the data is collected properly, then it helps to get the outcome in best possible way. In case of VSM the team member or members will collect the required data. The expected data in case of VSM is name of machine, number of shifts for which that particular machine is in use, operators per day for that machine, the tool charge time, setup time, percentage of defects, breakdown, preventive maintenance, loading & unloading time. The cycle time and overall lead times required for each process is also required to be recorded. The stop watch method is used to exactly measure the various times involved in it. The data collection also includes the demand of the customer.

Calculation of time measures

The next step is calculation of the time measures. The major factor in this is calculation of takt time. The takt time gives us the actual demand related to time. It means in how much time one component should be manufactured completely so as to meet the customer demand.

Drawing current state map

This step gives us the exact current situation about the product. To draft the map it is expected that the team should know the general symbols used for VSM. As the desired data is ready & time measures are available using the symbols the current state map is drafted. The map could be drawn using pencil and paper. Also use of softwares like Microsoft Vision can be done to draw the map. The map will consist of all the operations related to that product in sequence. The blocks related to each operation or process is drawn to show the details like cycle time, uptime. Below these blocks the time measures like value added and non value added time are written on the timeline. The total value added and non value added time is shown towards extreme right side of the time line.

Analyzing the current state map

The analysis of current state VSM is very important to reach to required solution. The timeline below the current state map easily indicates the value added & non value added times related to each process. Every process included in current state map is analyzed. As all the processes which are interlinked are shown on the map, it is possible to locate areas of improvement. The basic aim is to reduce the non value adding time so we can improve the productivity.

Identification of possible solutions

The analysis of current state map gives the idea about where exactly the problem is. What sort of problems and its intensity. The process of actual solution begins at this stage. All possible alternative solutions must be listed. The pros and cons related to each solution are studied. The main focus is to think on solution which involves low cost automation and with minimum or no disturbing the current manufacturing methodology. The solution commonly known as kaizen burst which is shown on map with particular symbol. Also the human factor should be considered. In some cases the operator has to perform an operation or handle the components in such a way that it causes fatigue to the operator. It may be due to lifting the component from floor level to table height, also from one location to other weight of the component, repeatability of the work. So while finalizing the desired solution, the focus should also be on reducing the operator fatigue.

Drawing future state map

After deciding the best possible solution for improvement, this solution is practically implemented. All necessary changes and suggestions are implemented. These changes now affect the time measures in a positive way. Definitely the changes will reduce the time for non value added activities. All these new time measures are recorded. With these new measures & using VSM symbols future state map is drawn. Similar to current state map, all non value added times are shown towards left side of the data table whereas the value added time is written below the table. The total value added & non value added times are shown on extreme right side of the future state map. Thus the future state map gives the exact picture of improved situation.

Assessment of productivity

The future state map shows us the clear picture of improvement in the current situation. This needs to be analyzed in terms of change in productivity. The effects on actual manufacturing are analyzed. Also the level of changes in profitability of company is increased. This is an important assessment in VSM implementation. Since all changes are suggested and implemented its feasibility in terms of cost benefits and its use to the organization is studied. In fact the changes made and improvement in productivity should be tabulated to clearly show the benefit. This assessment will definitely boost the confidence of the company entrepreneur as it is directly benefitting the company.

Sometime the assessment shows the result which are not up to the levels expected. A repeat study and analysis is suggested for post implementation study to decide on any improvement initiatives.

CONCLUSIONS

This theoretical model serves as guidelines for SMEs struggling to adopt lean principles and achieve sustainable growth in a competitive market. The research emphasizes an eight-stage approach to VSM implementation, beginning with problem identification and progressing through data collection, current state mapping, solution identification, and future state mapping, culminating in productivity assessment. Following are some important conclusions of this study.

- The model has a focus on SME-specific constraints such as financial limitations, low automation, and human resource challenges.
- Highlights key SME challenges like low awareness levels, resistance to change, limited skilled workforce, and financial constraints impacting quality improvement initiatives.
- It has considered the main aspects of SME which are low-cost automation, minimal process disruption, and operator considerations like fatigue and decision-making empowerment.
- It also highlights reduction of non-value-added activities to improve overall productivity, aligning with lean principles like Kaizen, 5S, and standardization.

REFERENCES

1. Rahani AR, Muhammad al-Ashraf, “Production Flow Analysis through Value Stream Mapping: A Lean Manufacturing Process Case Study”, Procedia Engineering 41 (2012) 1727 – 1734.
2. Xiaoning Zhu, Mahmood Hassan, “Lean Six Sigma”, Interdisciplinary Journal of Contemporary Research In Business, February 2012 Vol 3, No 10.
3. Matthias Goerke, Maurice Schmidta, Jan Buscha, Peter Nyhuis ,Holistic Approach of Lean Thinking in Learning Factories Procedia CIRP 32 (2015) 138 – 143.
4. M. Manjunath, Dr.H. C.Shivaprasad , K. S. Keerthesh Kumar, DeepaPuthran, “Value Stream Mapping as a Tool For Lean Implementation: A Case Study”, International Journal Of Innovative Research & Development, ISSN 2278 – 0211,Vol 3 Issue 5, May, 2014.
5. K. M. Khalid, Ahmad Y. B. Hashim and Mohd R. Salleh, “On Value Stream Mapping and Its Industrial Significance”, Journal of Industrial and IntelligentInformation Vol. 2, No. 2, June 2014.
6. Peter Hines, Nick Rich, “The seven value stream mapping tools”, International Journal of Operations& Production Management”, Vol. 17 Iss: 1, (1997), pp. 46 – 64.
7. Muhammad AbdusSamad, Md. Saifulalam, And Nishattusnim, “Value Stream Mapping To Reduce Manufacturing Lead Time In A Semi-Automated Factory”, Asian Transactions on Engineering (ATE ISSN: 2221-4267) Volume 02 Issue 06, January 2013.
8. R.M. Belokar, Vikas Kumar, Sandeep Singh Kharb, “An Application of Value Stream Mapping In Automotive Industry: A Case Study”, ISSN: 2278-3075, Volume-1, Issue-2, July 2012.
9. Ali Turkyilmaz, Ali Gorener, Humeyra Baser, “Value Stream Mapping: Case Study in a Water Heater Manufacturer”, Vol. 2, No. 2, June 2013.
10. Seyed Mohammadali Motavallian Hariprasad Settyvari, “Application of Value Stream Mapping in Product Development”, DEC 2013.
11. Neha Verma, Vinay Sharma, Energy Value Stream Mapping a Tool to develop Green Manufacturing,Procedia Engineering 149 (2016) 526 – 534.

12. Jafri Mohd Rohani and Seyed Mojib Zahraee, Production line analysis via value stream mapping: a lean manufacturing process of color industry.

13. L. F. Romero and A. Arce, Applying Value Stream Mapping in Manufacturing: A Systematic Literature Review, IFAC PapersOnLine 50-1 (2017) 1075–1086.

14. Dushyanth Kumar K R, Shivashankar G S and Rajeshwar S K,Application of Value Stream Mapping in Pump Assembly Process: A Case Study , Industrial Engineering & Management http://dx.doi.org/10.4172/2169-0316.1000162 .

15. L. R. Chaudhari, Uday A. Dabade, V. R. Angane, V.P.Auti, Lean manufacturing implementation for assembly kitting system using value stream mapping National Conference on Recent Trends in Mechanical Engineering (ncrtme2016),WCE,Sangali.

16. Kannan Jayaraman, Value stream mapping -Adapting lean management principle in the ESO Larson and Toubro Limited Integrated Engineering Services(IES) Chennai ,June 2010.

A Descriptive Study of Knowledge Management for Industry Chain

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ABSTRACT

Knowledge management (KM) plays a crucial role in improving the efficiency, innovation, and competitiveness of organizations across diverse industry chains. This study delves into the implementation of KM strategies tailored specifically for industry chains, with the goal of optimizing information flow, promoting collaboration, and capitalizing on intellectual assets within the intricate network of interconnected businesses. The paper thoroughly examines key concepts in knowledge management and their adaptation to the dynamics of industry chains. It underscores the significance of identifying, acquiring, storing, disseminating, and applying knowledge throughout the value chain. Additionally, the study investigates the transformative role of emerging technologies like artificial intelligence, big data analytics, and block chain in reshaping knowledge management practices within industry chains.

INTRODUCTION

Industry chains, encompassing diverse stakeholders from raw material suppliers to end consumers, operate in a landscape marked by rapid technological advancements, global competition, and ever-evolving market demands. In such a context, the ability to effectively harness and capitalize on the wealth of knowledge distributed across the entire value chain becomes paramount. This paper explores the nuanced dimensions of knowledge management tailored to the intricacies of industry chains, shedding light on the challenges, opportunities, and best practices associated with implementing effective KM strategies. The overarching objective of this research is to underscore the significance of knowledge management in optimizing industry chain operations. As organizations navigate through the stages of production, distribution, and consumption, they encounter various knowledge-related challenges – from ensuring the quality and timeliness of information exchange to promoting a culture of collaboration and continuous learning. By examining the specific needs of industry chains, this study aims to offer insights that can inform and guide organizations in developing robust knowledge management frameworks aligned with the unique demands of their respective value chains. Throughout this exploration, we will delve into key components of knowledge management, covering aspects from knowledge creation and acquisition to dissemination and application. Additionally, we will scrutinize the role of cutting-edge technologies in transforming knowledge management practices within industry chains and explore the organizational and leadership elements essential for fostering a culture of knowledge-sharing. Through these efforts, we seek to contribute to the ongoing discourse on knowledge management for industry chains and provide a foundational resource for organizations navigating the complexities of today's interconnected business ecosystems.

FUTURE USES

Academic Databases

These databases contain a diverse collection of scholarly articles spanning various fields. To find articles related

to knowledge management in industry chains, utilize keywords such as "knowledge management," "industry chain," "supply chain," and other relevant terms during your search. Employ Boolean operators such as AND, OR, and NOT to fine-tune your search, enabling a more targeted exploration of scholarly literature.

Journal in Knowledge Management

Explore specialized journals in knowledge management to access in-depth articles and research papers. Consistently monitor these journals for the most recent publications on strategies for knowledge management within industry chains.

Research Organization

Investigate reports on industry trends from research organizations and think tanks, as they frequently publish valuable insights. Explore publications from these reputable sources to gain a deeper understanding of knowledge management practices within industry chains.

Conference Proceeding

Participate in conferences focused on knowledge management, supply chain management, and industrial practices to showcase cutting-edge research. Stay informed by reviewing conference proceedings, including those from events like the International Conference on Knowledge Management or Supply Chain Management conferences, to access the latest research findings.

Books and Book Chapters

Books and book chapters authored by experts can provide comprehensive coverage of the subject. Search platforms like Google Books or Amazon for titles related to knowledge management in industry chains.

IMPLEMENTING KNOWLEDGE MANAGEMENT

Conduct a Knowledge Assessment

Start by assessing the existing knowledge assets, both explicit and tacit, within the industry chain. Identify critical knowledge areas, key stakeholders, and potential knowledge gaps.

Define Objectives and Goals

Clearly articulate the objectives and goals of implementing knowledge management. Determine what the organization aims to achieve through effective knowledge management within the industry chain, such as improved collaboration, innovation, and operational efficiency.

Develop a Knowledge Management Strategy

Formulate a comprehensive KM strategy that aligns with the specific needs and characteristics of the industry chain. Consider the unique challenges and opportunities presented at different stages, from raw material suppliers to end consumers.

Establish Governance and Leadership

Appoint leaders and establish governance structures to oversee the knowledge management initiative. Assign responsibilities for knowledge stewardship, ensuring that there is accountability for the success of KM practices throughout the industry chain.

Create a Knowledge Sharing Culture

Foster a culture that encourages knowledge sharing and collaboration. Implement incentives, recognition programs, and communication strategies to promote the value of sharing insights and expertise across stakeholders.

Implement Technology Solutions

Leverage technology to facilitate knowledge management processes. Implement collaborative platforms, document management systems, and other tools that enable seamless sharing and retrieval of information within the industry chain.

Capture and Codify Knowledge

Develop processes for capturing tacit knowledge and converting it into explicit forms. Create knowledge repositories, databases, or wikis to store and organize information relevant to different stages of the industry chain.

Provide Training and Support

Offer training programs to educate stakeholders on the importance of knowledge management and how to use the implemented tools effectively. Provide ongoing support to address any challenges and ensure the continuous adoption of KM practices.

Encourage Cross-Functional Collaboration

Facilitate collaboration among different functions and entities within the industry chain. Promote cross-

functional teams and collaborative projects to enhance knowledge exchange and problem-solving.

Measure and Evaluate

Establish key performance indicators (KPIs) to measure the success of knowledge management initiatives. Regularly evaluate the impact on efficiency, innovation, and overall performance within the industry chain.

Iterate and Improve

Knowledge management is an evolving process. Continuously gather feedback, learn from experiences, and iterate on the KM strategy to address changing dynamics and emerging challenges within the industry chain.

Document Best Practices

Document successful knowledge management practices and lessons learned. Share these insights across the industry chain to encourage the replication of effective strategies and processes.

EXPECTED BARRIERS OF THE PROPOSAL MODEL

Resistance to Change

Employees at various stages of the industry chain may resist changes in their established workflows and practices. A cultural shift towards knowledge sharing and collaboration may face resistance, particularly if employees perceive it as disrupting their routine or job security.

Lack of Leadership Buy-In

Without strong support from leadership and a clear commitment to knowledge management principles, the initiative may lack the necessary resources, visibility, and influence to succeed. Leaders must actively champion the importance of KM and integrate it into the organization's strategic goals.

Technology Adoption Challenges

Implementing new technologies for knowledge management can be met with challenges, including technical complexities, integration issues with existing systems, and a learning curve for users. Ensuring user-friendly interfaces and providing comprehensive training can help mitigate these challenges.

Data Security and Privacy Concerns

The sharing of knowledge often involves sensitive information. Concerns about data security, privacy, and intellectual property protection may arise. Establishing robust security measures and clear policies is crucial to address these concerns and build trust among stakeholders.

CONCLUSION

In summary, integrating knowledge management (KM) into an industry chain is a strategic necessity for organizations aiming to excel in the contemporary and interconnected business landscape. The diverse network of stakeholders, spanning from raw material suppliers to end consumers, calls for a comprehensive approach to knowledge management that encompasses the entire value chain. Throughout this extensive study, we have delved into crucial considerations and steps essential for effectively harnessing and leveraging knowledge to optimize the operations of industry chains. The study consistently underscores the significance of knowledge identification, acquisition, storage, dissemination, and application. Recognizing the distinctive challenges and opportunities at each stage of the industry chain, organizations must tailor their KM strategies to address specific needs and complexities. Whether the focus is on enhancing collaboration, fostering innovation, or improving operational efficiency, KM emerges as the pivotal factor in unlocking the untapped potential inherent in the collective intelligence of the industry chain.

REFERENCES

1. https://ied.eu/blog/importance-of-knowledge-management-in-supply-chain-management/
2. https://www.sciencedirect.com/science/article/abs/pii/S0957417411015788
3. https://www.getguru.com/reference/knowledge-management-supply-chain-management
4. https://www.iese.edu/media/research/pdfs/DI-0900-E.pdf
5. https://scholarspace.manoa.hawaii.edu/server/api/core/bitstreams/0ef0aaf9-0a2d-44a4-abad-d5748c8d57e8/content

Impact of Emotional Intelligence on Innovative Work Behavior: A Study of Leader-Follower Dyads in the state of Punjab

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ABSTRACT

Modern organizations are getting increasingly dependent on innovation as a survival and growth tool in cutting edge competition and highly dynamic environment. Past research has established link between organizational leadership and innovative work behavior of employees. Drawing upon the emotional intelligence theory, we have examined the impact of leaders' emotional intelligence on innovative work behavior of the followers using Vertical Dyad Linkage (VDL) Model.

A snowballed sample of 280 leader-follower dyads was drawn from advocates registered in the state of Punjab who worked in advocate offices and law firms. The leaders reported their own emotional intelligence and also the innovative work behavior of their followers on an adapted five point likert scale. The data were analyzed with structural equation modeling using SPSS AMOS.

The findings confirmed that leaders' emotional intelligence has significant positive impact on innovative work behavior of followers as well as its four underlying dimensions. The study has contributed in further advancement of emotional intelligence theory in the new landscape of leader-follower dyads. The given practical implications can be a ready reference for leadership scholars and practitioners to stimulate organizational innovation.

KEYWORDS: *Emotional intelligence, Innovative work behavior, Leader-follower dyads, Vertical dyad linkage model.*

INTRODUCTION

The modern businesses are operating in a complex and highly dynamic environment. In order to sustain cut throat competition, they are bound to rely on innovation. In fact, today, the firms need innovation and business creativity as a competence, not a coincidence (Janszen, 2000). Creativity means coming up with new and helpful ideas in any area, while innovation is when these ideas are put into action and are implemented within the work group or organization.

Although there are various factors that contribute to how employees engage in innovative tasks, this study focuses on contextual factors of leadership and especially the emotional intelligence of leaders. It was in 1990 that Salovey and Mayer (1990) coined the term Emotional Intelligence. They asserted about emotional intelligence that it is, "the core capacity to access one's own feeling and that of others; the capacity to effect discriminations among these feelings and, eventually, to label them, to enmesh them in symbolic codes, to draw upon them as a means of understanding and guiding one's behavior". As per the extant literature, leadership has always played a key role in stimulating innovative work behavior amongst employees. Afsar et al. (2014) established a positive link between transformational leadership and innovative work behavior. While Mansoor et al., (2021) have proved that inclusive leadership has a positive impact on innovative work behavior of employees. This study has focused on underlying aspect of leaders' emotional intelligence and ventured into examination of the impact of leaders'

emotional intelligence on innovative work behavior of the followers. Although the past literature has examined relationship of emotional intelligence with innovative work behavior, however this examination has broadly remained confined to either managers' level or employees' level. There are hardly any studies which examined how leaders' emotional intelligence affect followers innovative work behavior. The present study is aimed to fill this gap in literature and examine the contextual role of leaders' emotional intelligence on followers' innovative work behavior. This study has used the Vertical Dyad Linkage (VDL) theory of Dansereau et al. (1975) under which the framework of leader-follower dyad was used as an individual cell of unique relationship between a leader and a particular follower. The study has examined impact of leader emotional intelligence on follower innovative work behavior in a particular dyad. Hence this VDL model was used as a framework to test the hypotheses in our study. Our study has attempted to answer the following research question:

- Does the emotional intelligence of leaders have a positive impact on innovative work behavior of followers?

REVIEW OF LITERATURE

Innovative Work Behavior

It is the behavior of employees to create, introduce and apply new ideas intentionally at work, within a group or an organization for contributing to performance (Janssen, 2000). For the purpose of this study, the definition of Innovative Work Behavior (IWB) was taken from De Jong and Hartog (2008) as a person's actions focused on starting and intentionally bringing in fresh and helpful ideas, methods, products, or procedures within a job, team, or organization. Their model distinguishes four dimensions of Innovative Work Behavior as: opportunity exploration; idea generation; championing and implementation.

Emotional Intelligence

The construct of emotional intelligence gained momentum in 1990s when Salovey and Mayer (1990) propounded the term and gave the theory of emotional intelligence. Bar-On (1997) defined it as "Emotional Intelligence is an array of non-cognitive capabilities, competencies and skills that influence one's ability to succeed in coping with environmental demands and pressures". For the purpose of this study, we operationalized the construct of emotional intelligence using Wong and Law (2002) definition as "The ability to perceive accurately, appraise, and express emotion; the ability to access and/or generate feelings when they facilitate thought; the ability to understand emotion and emotional knowledge; and the ability to regulate emotions to promote emotional and intellectual growth". Wong and Law (2002) have propounded four dimensions of emotional intelligence as self-emotional appraisal; others-emotional appraisal; regulation of emotion; use of emotion.

Emotional Intelligence and Innovative Work Behavior

The extant literature has widely covered the linkage of emotional intelligence and innovative work behavior at the same individual level; be it at leader's level or employee's level. However, literature is scarce regarding impact of leaders' emotional intelligence on followers' innovative work behavior. Andrabi and Rainayee (2020) conducted an extensive literature review and found that employees' emotional intelligence greatly enhances their innovative work behavior. Significant positive correlation has been reported between one's emotional intelligence and innovative work behavior as per the findings of Shojaei and Siuki (2014). As per findings of Oyadiwa (2022), emotional intelligence has significant impact on innovative work behavior of employees. And this impact was mediated through tacit knowledge sharing. As per Diana and Sudarma (2021), emotional intelligence and transformational leadership significantly influences innovative work behavior. Ivcevic et al. (2021) have found that leader's emotional intelligence has significant positive impact on employee's creativity and innovation through a serial mediation effect of employee opportunity to grow and higher experience of positive affect.

In light of the above findings, we hypothesize as under:

H1: Emotional intelligence of leaders has a significant positive impact on innovative work behavior of followers.

Research Design, Participants and Procedure

The sampling unit was leader-follower dyads working as advocates in the law firms and advocate offices and practicing law at district level courts and high court in the state of Punjab (India). Using snowball sampling based on referrals, data was collected from 280 leader-follower dyads. Out of 280 leaders, 251 were males, and 29 were females. Out of 280 followers, 231 were males, and 49 were females. Further, out of 280 dyads, 71 worked at Punjab and Haryana High Court while 209 worked at district level courts. The data was collected from leaders who represented their respective dyads. Leaders reported innovative work behavior of followers on a 10 item (4 dimensions) likert scale (adapted from De Jong and Hartog, 2008). Leaders also self-reported their own emotional intelligence on a 16 items (4 dimensions) likert scale (adapted from Wong and Law, 2002). Both these scales were calibrated from 1 (strongly disagree) to 5 (strongly agree). The data was analyzed through structural equation modeling (SEM) using SPSS and AMOS 21.

RESULTS

The descriptive statistics were worked out in the form of mean and standard deviation for both the constructs and values are reflected in Table 1 along with the inter-construct correlation. The scale reliability for both the constructs of emotional intelligence and innovative work behavior was assessed in the form of Cronbach's Alpha and the values came out to be 0.947 and 0.934 respectively (diagonal values in Table 1). As both of these values are higher than threshold of 0.7 (Nunally, 1978), we have adequate reliability of scales of emotional intelligence and innovative work behavior to proceed ahead for further statistical analysis.

Table 1: Descriptive statistics of study variables

	Variable	Mean	SD	1	2
1	Emotional Intelligence	3.902	0.757	**(0.947)**	
2	Innovative Work Behavior	3.693	0.898	0.491**	**(0.934)**

Note: N = 280. Cronbach's alpha in diagonal.

** p < 0.01

Source: Authors' own work

Measurement Model Assessment

Second order confirmatory factor analysis (CFA) was run using SPSS AMOS 21 on the basis of a priori approach of theory of scale development of both constructs of emotional intelligence and innovative work behavior. As both these constructs are multidimensional, the respective items were loaded on their concerned factors and resulting CFA model is shown in Figure 1.

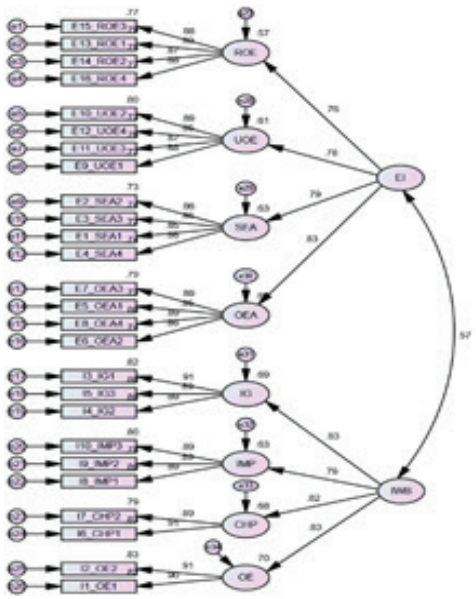

Fig. 1: CFA model of emotional intelligence and innovative work behavior

Source: Authors' own work

This model had an acceptable fit with chi-square [290] = 304.038; comparative fit index = 0.998; standardized root mean square residual = 0.033 and root mean square error of approximation = 0.013. These fit indices reflect that our model has good fit as per cut off values of Hu and Bentler (1999). The convergent and discriminant validity of this model were assessed as per figures shown in Table 2.

Table 2: Validity of CFA model of EI and IWB as per Fornell and Larcker Criterion (1981)

Construct	CR	AVE	MSV	EI	IWB
EI	0.920	0.742	0.408	**0.862**	
IWB	0.937	0.789	0.408	0.639**	**0.889**

Note: EI = emotional intelligence; IWB = innovative work behavior; CR = composite reliability; AVE = average variance extracted; MSV = maximum shared variance. N = 280

***p < 0.01
Source: Authors' own work

For convergent validity of a construct, CR > 0.7; AVE > 0.5 and CR > AVE. As this condition holds good for both constructs of emotional intelligence and innovative work behavior (Table 3), it shows that measurement model has good convergent validity.

For discriminant validity, AVE > MSV and this condition also holds good in Table 3. Also, as per Fornell and Larcker Criterion (1981), the diagonal values (square root of AVE) must be greater than inter-construct correlations and this condition also holds good in Table 3. Further, the Heterotrait-Monotrait Ratio (HTMT Ratio) between the constructs of emotional intelligence and innovative work behavior is 0.571 which is less than threshold value of 0.85 (Henseler et al., 2015). Thus our measurement model has good discriminant validity.

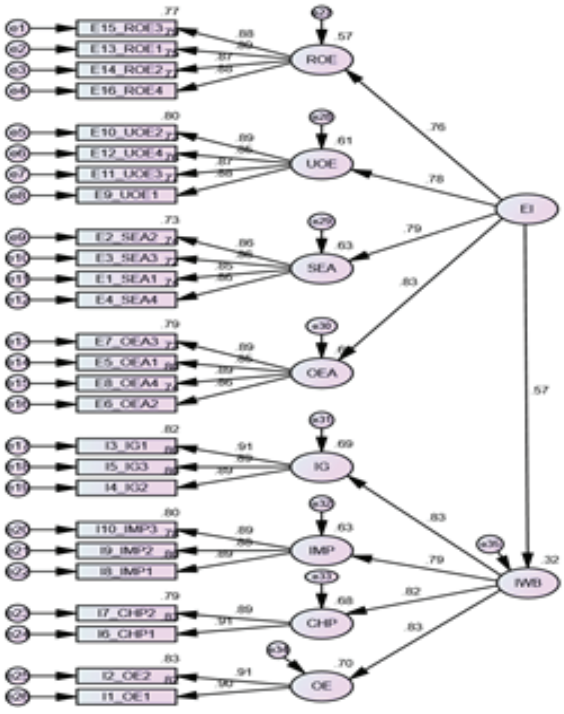

Fig. 2: Full structural model of emotional intelligence and innovative work behavior
Source: Authors' own work

In light of good model fit, convergent and discriminant validities of the measurement model, we can proceed for structural equation modeling and the consequent structural model is shown in Figure 2.

The structural model had an acceptable fit with similar values as of measurement model: chi-square [845] = 845.143; comparative fit index = 1.000; standardized root mean square residual = 0.037 and root mean square error of approximation = 0.001. These fit indices reflect that our model has good fit as per cut off values of Hu and Bentler (1999).

The direct effects were assessed from the path coefficients (β) and their significance (Table 3).

Table 3: Analysis of the Direct Effect

Hypothesis & Relationship		β value	t-value	p-value	R-Square	Conclusion
H1	EI→ IWB	0.567	7.351	***	0.322	Accepted

Note: EI = emotional intelligence; IWB = innovative work behavior; OE = opportunity exploration; IG = idea generation; CHP = championing; IMP = implementation; N = 280;
***p < 0.001

Source: Authors' own work

DISCUSSION

As evident from Table 3, direct effect is significant. It implies that emotional intelligence of leaders has significant positive impact on innovative work behavior of their followers (β = 0.567, p < 0.001) which leads to acceptance of H1.

The R-Square values signify the total variance explained by independent variable in the dependent variable (Hair et al., 2021).

As shown in Table 3, the R-Square values for H1 (EI→IWB) is above 26% which implies substantial effect (large variance explained) as per Cohen (1988). However, it is to be observed that as our hypothesis has been accepted leading us to the conclusion that emotional intelligence of leaders exerts significant positive impact on innovative work behavior of followers. Our findings are consistent with Tsakalerou (2016) whose findings have indicated that emotional intelligence competencies

act as antecedents of innovation. These findings are also corroborated by Zhang et al. (2015) and Ivcevic (2021) who indicated that emotional intelligence has significant positive association with innovation performance.

Theoretical Implications

Our study has filled a key research gap by proving that leaders' emotional intelligence paves way for followers' innovative work behavior whereas the past research has predominantly established linkage of emotional intelligence and innovative work behavior at either the leaders level or the employees level.

Secondly, our study has opened new theoretical paths of considering leaders' emotional intelligence as a key antecedent for certain more positive outcomes. While we have just established linkage of emotional intelligence with innovative work behavior. At the same time, there has been certain empirical evidence that innovative work behavior has positive association with job performance as well as job satisfaction (Suryani, 2019; Rosdaniati and Muafi, 2021). While certain studies have also established direct effect of emotional intelligence on job performance and job satisfaction (Winton, 2022; Elayan et al., 2023). This leads us towards the possible direction of exploring mediation effect of followers' innovative work behavior on the relationship between leaders'' emotional intelligence and followers' job performance and job satisfaction.

Practical Implications

The central finding of our study is statistical proof of the fact that if leaders act with emotional intelligence, they can stimulate innovative work behavior amongst their followers. Based on these findings, following practical implications emanate for the scholars and practitioners of leadership and their followers:

Leaders may keenly observe their own emotions and learn to identify and discriminate them on the basis of a close assessment. They can go for repeated rehearsals and discussion with their team to get feedback and enhance their self-emotion appraisal. They should try to read body language and non-verbal communication of people around them and assess others emotional state by paying conscious attention to this aspect. Informal communication off the official roles can be a great help to more accurately check others emotional state.

Followers on the other hand cannot be modelled as robots who are merely programmable by their leaders to generate innovative work behavior. In fact, the IWB is purely an extra role behavior and has a huge voluntary element in it. This needs the followers to be highly proactive and rise above expectations. They may keep looking for ways to improve the current methods, services or products. Think of the work processes in alternative ways bringing multiple perspectives.

Limitations and future research

The study has investigated contextual factors of innovative work behavior by examining the role of leaders' emotional intelligence while there might be plenty of intrapersonal factors which may highly influence followers innovative work behavior. This study deployed a cross-sectional design and in order to establish firm causality, longitudinal studies may be conducted across different sectors and cultures in future to enhance the generalizability of our findings.

REFERENCES

1. Afsar, B., F. Badir, Y., & Bin Saeed, B. (2014). Transformational leadership and innovative work behavior. Industrial Management & Data Systems, 114(8), 1270-1300.
2. Andrabi, N. F., & Rainayee, R. A. (2020). Emotional intelligence and innovative work behaviour: A review. International Journal of Engineering and Management Research, 10.
3. Bar-On, R. (1997). BarOn emotional quotient inventory (Vol. 40). Multi-health systems.
4. Dansereau Jr, F., Graen, G., & Haga, W. J. (1975). A vertical dyad linkage approach to leadership within formal organizations: A longitudinal investigation of the role making process. Organizational behavior and human performance, 13(1), 46-78.
5. De Jong, J. P., & Den Hartog, D. N. (2008). Innovative work behavior: Measurement and validation. EIM Business and Policy Research, 8(1), 1-27.
6. Diana, L. N., & Sudarma, K. (2021). The effect of emotional intelligence and transformational leadership on innovative work behavior with psychological empowerment as a variable mediation. Management Analysis Journal, 10(2), 223-232.

7. Elayan, M. B., Albalawi, A. S., Shalan, H. M., AL-HOORIE, A. H., & Shamout, M. D. (2023). Perceived manager's emotional intelligence and happiness at work: The mediating role of job satisfaction and affective organizational commitment. Organizacija, 56(1), 18-31.

8. Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. Journal of marketing research, 18(1), 39-50.

9. Henseler, J., Ringle, C. M., & Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. Journal of the academy of marketing science, 43, 115-135.

10. Hu, L. T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Structural equation modeling: a multidisciplinary journal, 6(1), 1-55.

11. Ivcevic, Z., Moeller, J., Menges, J., & Brackett, M. (2021). Supervisor emotionally intelligent behavior and employee creativity. The Journal of Creative Behavior, 55(1), 79-91.

12. Janssen O (2000) Job demands, perceptions of effort–reward fairness and innovative work behavior. J Occup Organ Psychol 73:287–302

13. Janszen, F. (2000). The age of Innovation. Making business creativity a competence, not a coincidence.

14. Mansoor, A., Farrukh, M., Wu, Y., & Abdul Wahab, S. (2021). Does inclusive leadership incite innovative work behavior?. Human Systems Management, 40(1), 93-102.

15. Nunnally, J. C. (1978). An overview of psychological measurement. Clinical diagnosis of mental disorders: A handbook, 97-146.

16. Oyadiwa, R. (2022). Effect of Emotional Intelligence to Innovative Work Behavior of Employees Mediated with Tacit Knowledge Sharing in Education Department of Aceh. Jurnal Kawistara, 12(1), 49-63.

17. Podsakoff, P. M., MacKenzie, S. B., Lee, J. Y., & Podsakoff, N. P. (2003). Common method biases in behavioral research: a critical review of the literature and recommended remedies. Journal of applied psychology, 88(5), 879.

18. Rosdaniati, R., & Muafi, M. (2021). The influence of workplace happiness and innovative work behavior on job satisfaction mediated by work engagement. International Journal of Research in Business and Social Science (2147-4478), 10(7), 186-198.

19. Salovey, P., & Mayer, J. D. (1990). Emotional intelligence. Imagination, cognition and personality, 9(3), 185-211.

20. Shojaei, M., & Siuki, M. (2014). A study of relationship between emotional intelligence and innovative work behavior of managers. Management Science Letters, 4(7), 1449-1454.

21. Suryani, I. (2019, August). Psychological empowerment, innovative work behavior and job satisfaction. In 3rd International Conference on Accounting, Management and Economics 2018 (ICAME 2018) (pp. 636-643). Atlantis Press.

22. Tsakalerou, M. (2016). Emotional intelligence competencies as antecedents of innovation. Electronic Journal of Knowledge Management, 14(4), pp207-219.

23. Winton, B. G. (2022). Emotional intelligence congruence: the influence of leader and follower emotional abilities on job satisfaction. Leadership & organization development journal, 43(5), 788-801.

24. Wong, C. S., & Law, K. S. (2002). Wong and law emotional intelligence scale. The leadership quarterly..

25. Zhang, S. J., Chen, Y. Q., & Sun, H. (2015). Emotional intelligence, conflict management styles, and innovation performance: An empirical study of Chinese employees. International journal of conflict management, 26(4), 450-478.

A High Performance E-Voting System Design with Side Chains using Machine Learning

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ABSTRACT

E-voting needs to be fast and safe, with distributed processing, immutability, traceability, and transparent voting as prerequisites. Blockchain satisfies all these requirements; thanks to hash-based linking, data saved on the chain is immutable and can be tracked back to its original source. Furthermore, the network is inherently transparent and has great performance because the stored data is validated by distributed miner and verifier nodes. However, the storage latency, retrieval time, and access capabilities are all dramatically increased when e-voting data is stored on a single blockchain structure. This is due to the fact that each new block added to the chain must have its hash value compared to the existing blocks in order to guarantee uniqueness. Designers apply distinct hash criteria in addition to confirming that hashes are unique. For instance, the first eight bytes of a hash must be zeros according to the Bitcoin blockchain. These rules are enforced by computationally complex algorithms that aim to generate controlled stochastic numbers to improve block production and verification efficiency.

The performance of these algorithms is further hampered by longer chains, which reduces the overall quality of service (QoS) of the system. This study presents a QoS-aware e-Voting system that leverages intelligent side chains to enhance the performance of blockchain mining and verification for big chain systems. By using a multi-objective genetic algorithm model, the system model seeks to reduce the computational cost of block addition, verification, and access. By employing probability analysis to create dynamic side chains intelligently, the approach can reduce block formation and access latency while simultaneously improving scalability.It has been noticed that the suggested model, when compared to the typical Ethereum single chained e-Voting implementation, can cut end-to-end delay by 10% and energy consumption by 15%.

KEYWORDS: *Machine Learning, Side Chain, E-Voting, Blockchain.*

INTRODUCTION

Designing e-Voting systems requires development of party registration, voter registration, voting process design, and counting phase design. A high-performance e-Voting system is expected to be highly secure in terms of registration processes, immutable in terms of voting process design and transparent in terms of counting phase design.

Voters and parties use biometrics and ID cards for voter registration. Voters can then submit their ballots to the appropriate parties. The blockchain's nodes will store this vote data.

Data from these nodes is aggregated onto an admin module, wherein a transparent voting process is used in order to check vote authenticity [1]. The following block structure is used by e-Voting blockchains to store voting information,

Voter's ID (can be Aadhaar card, Passport, voter card, etc.) [2], Vote of the voter, Signature of the voter, Timestamp at which vote is casted, Voter's location for verification against pre-set electoral roll, Nonce number for the block, Hash of previous block.

Based on this structure, the nonce value is modified in order to generate new blocks. To perform this action,

a wide variety of stochastic algorithms are available, each of which has their own nuances, advantages and limitations [3]. A survey of these algorithms can be observed from the next section, which will allow researchers to select the best mining algorithms for e-Voting process. Each of these algorithms use a variation of blockchain implementation in order to generate new blocks. The proposed blockchain sharding paradigm based on Genetic Algorithms is explained in Section 3, along with an empirical parametric study to improve the performance of such algorithms. Finally, this text concludes with some interesting observations about the proposed model, and recommends methods to improve it.

LITERATURE REVIEW

Designing secure and efficient e-Voting system models requires the underlying implementation to have immutability, transparency, traceability, and distributed storage capabilities. For example, the work in [4] suggests using a blockchain with a proof-of-work (PoW) architecture to improve the legitimacy of blockchain voting. This process has high security, but its performance reduces as number of blocks in the chain is increased. To remove this drawback, the work in [5] proposes use of smart contracts for e-Voting using bio-hashes. The system is highly reconfigurable, and has better speed and scalability when compared with [4], thereby it can be applied for a wider number of scenarios. An instance of this application to private voting can be observed from [6], wherein private blockchains are used. This enables underlying system model to have low delay and high security, as the system is safe from any external access. A study of such systems, and their nuances, advantages & limitations can be observed from [7], wherein solutions like trusted execution environments, blockchain sharding, encrypted biometrics, and proof-of-stake [8] are defined. These solutions assist in improving over quality of service (QoS), and voter experience while casting votes to the system. Similar review models are described in [9], wherein blockchain sharding, and selective encryption are recommended for better security. A highly secure, and highly scalable model that uses blockchain sharding can be described in [10].

The model is able to achieve this performance via intelligently maintaining small blockchain parts (called as sidechains), and then performing voting via these parts. These models can be applied to private blockchains [11], for further enhancing their performance. An application of this system can be observed from [12], wherein United States (US) electoral voting was managed using blockchains. It is evident that blockchains perform better than alternative models in terms of speed and security. thereby making them the best option for fast and extensive e-Voting system implementations. Similar applications can be observed from [13], [14] and [15]; wherein voting systems for India, Iraq and other large-scale organizations is mentioned. Using this information, it can be observed that side chain models are required for moderate to large-scaled systems for improving their overall performance. Author specific implementations of blockchains for eVoting can be observed from [16], [17], [18] and [19], wherein FOO schemes, AMV chain, manipulation prevention models, and Proof-of-Vote (PoV) consensus are defined. All these models aim at solving the issue of secure e-Voting via modifying encryption, access control and vote proof methods. Other methods that aim at reducing delay and improving overall QoS for blockchain deployments can be observed from [20], wherein methods like Blockchain Ballot, and i-Voting models are described.

High performance applications of e-Voting using blockchain can also be observed from [21], [22], [23], [24], and [25]; wherein large-scale deployment of blockchains is described. These deployments can be targeted to any application, but are specifically designed for eVoting, and showcase good performance as number of e-Voting entities is increased. P2P implementations are also described in [26], [27], [28] and [29]; wherein highly transparent system models for improving e-Voting speed and reducing its energy consumption are defined. These models have the capability for scaling to over 100 Million e-Voters, thereby improving their scalability performance. Blockchain can also be applied using Stellar Consensus, and high-performance vote verification as described in [30], and [31]; which makes it clear that blockchains are the road to any futuristic e-Voting solution. Inspired by this, the next section proposes an MGA based e-Voting model, that reduces overall delay of voting, and optimizes energy consumption across different applications.

Blockchain-based electronic voting system with sharding multi-objective genetic algorithm

The length of the blockchain will continue to grow as more vote data is submitted, and the computational difficulty of adding additional nodes will likewise rise. The computation time required to add a new block is provided by (Dadd),

$$Dadd = N*Dread+N*Dcompare+Dwrite+K*compute \quad (1)$$

The delays for reading, writing, comparing, and computing the block's hash are represented by the variables Dread, Dcompare, Dwrite, and D compute. K is the number of cycles needed to calculate the new block's unique hash. Reducing the length of the blockchain or the number of cycles needed to use a multiobjective evolutionary algorithm to determine the new block's unique hash value can both shorten the time needed to add a new block to the blockchain. For effective electronic voting, multiple side chains are built, including those for creation, searching, and updating. By employing side chains to alter factors pertaining to delay, throughput, and storage cost, it is possible to achieve improved e-voting performance. MOGA is used to design judgments about side chain generation and splitting based on input parametric circumstances.

E-VOTING BLOCKCHAIN BASED ON SHARDING

Scalability issue resolved by adopting blockchain technology using sharding database technique. Transactions split among various small groups of nodes called shards. Because all shards operate in tandem, fewer computations, storage units per node, and computations are needed, allowing for larger networks. The following parameters are fed into the genetic algorithm to create a side chain: the number of solutions; the number of iterations;

The variables under consideration are: learning rate; side chain maximum and minimum lengths; percentage of performance variance; current side chains (Scurrent); and instances of e-voting to be added (Ievoting).

Output of MGA

Adding instances of e-voting to the side chain by getting side chain number.

All solutions are marked as cross overed

From one to the number of iterations (Ni), repeat the procedure.

Getting the solution for 1 to number of solutions(Ns)

Check for each solution ,if it cross overed then no need to modify it and pass it to the next solution.

Otherwise search the random chain from the available list of chains and mark it as selected (Sselected)

E-voting instances will get added to the selected chain fitness will be evaluated by,

$$f_j = \sum_{i=1}^{L(I_{evoting})} k_i * D_{calculate_i} \Big/ L(I_{evoting}) + L(I_{evoting}) * (D_{read} + D_{compare}) + D_{write} \quad (2)$$

where L(Ievoting) is the number of e-voting instances added to the chain and j is the number of solutions.

Percentage variation is evaluated by,

$$P_v = 100 * \frac{f_j - f_{j(prev_{iteration})}}{f_j} \quad (3)$$

fj(previteration)is the fitness solution of previous iteration and fj is the current solution fitness for the iteration.

Compare percentage variation with performance percentage variation ,if P<Pperf then accept the solution otherwise evaluate the solution by again equation (2). Using another side chain.

Check weather all solutions for all chains not able to reduce the percentage variation then create new side chain. Threshold fitness value is estimated using equation (4)

$$f_{th} = \frac{\sum_{i=1}^{N_s} f_i * L_r}{N_s} \quad (4)$$

If the fitness is less than threshold fitness then mark solution as cross overed otherwise not to be cross overed. After all iterations are completed and need to create new side chain then create it with Ievoting as initial element and the length of side chain will be ,

Slength =L(Ievoting)+rand(Lmin,max) (5)

Now the future instances will be added using this sidechain. Searching of sidechain instances with the help of hash range. For each e-voting block hash range is decided as the searching of side chain instances is the complicated task during vote counting.

Structure of central blockchain contain Previous hash, Side chain ID, Party ID, Hash range ,Timestamp, Nonce. Whenever new side chain is created its information will be stored in the central blockchain. Depending party ID hash range will be selected and the block will be searched through its side chains. Due to this mechanism delay will be reduced and speed of the vote counting will be improved. For each new e-voting instances the hash values are estimated. Hash range of side chain can be extended if the hash value is not found in the given side chain.

For each e-voting block hash value is calculated which contain, Voter's ID, Vote of the voter, Signature of the voter, Timestamp, Voter's location, Nonce, Previous hash

If the calculated hash of the current e-voting block is exist in the current side chain block range then add the vote information to the chain. Otherwise extension of the side chain range and central blockchain will updated with this range. Reduction in chain length and searching of hash range. Overall delay of the e-voting will get reduced.

PERFORMANCE EVALUATION AND COMPARISON

Performance evaluation of the proposed side chain model can be applied to small organizations with less than 1000 employees, moderate sized states and large sized countries. Simulation is done by using solidity language. It is observed that energy consumption will get reduced by 2% compared with the standard model.

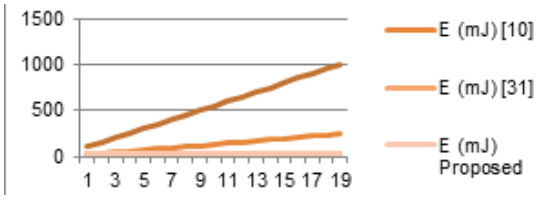

Fig. 1 Small sized organization overall energy consumption was reduced by 2%

For moderate sized organization overall energy consumption was reduced by 10% shown in fig 2.

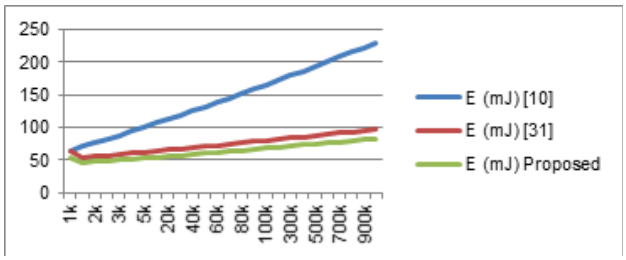

Fig. 2 Moderate sized organization overall energy consumption was reduced by 10%

For large scale organization overall energy consumption was reduced by 15% shown in fig. 3

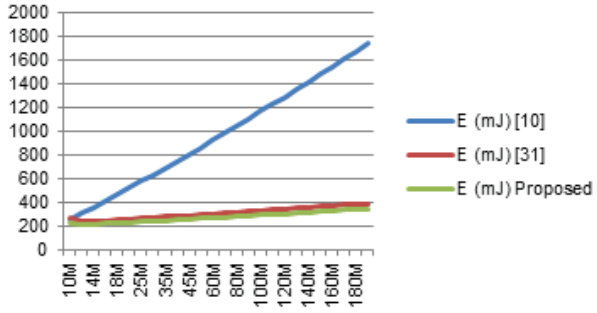

Fig. 3 Large scale organization overall energy consumption was reduced by 15%

We determined the number of transactions completed in a second (throughput), which is determined by the block size, transaction size, and block generation rate.

Tn=Bdmax/Ts/Bt

where Bdmax is the maximum amount of data stored in a block, was used to analyze the scalability of the proposed e-voting system. The average of all hexadecimal characters is divided by two to determine the transaction size, or Ts. Block generation rate is denoted by Bt.

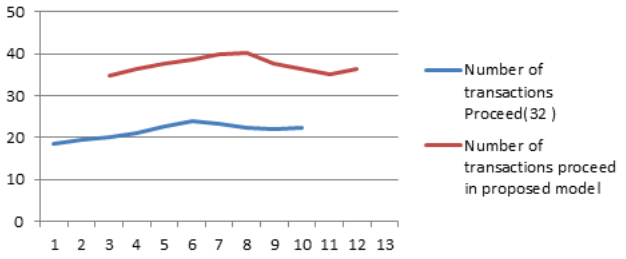

Fig. 4 Comparison of scalability

CONCLUSION

Blockchain's potential applications in a variety of industries have drawn interest, however scalability issues need to be resolved before using it. Scalability issues can be resolved in a variety of methods, including side chains, child chains, inter-chains, off-chains, and on-chains. In this study, we addressed how sharding, a side chain, might improve scalability. The platform that is used to integrate blockchain technology is also crucial. According to the evaluation, the suggested model with side chain has lower energy consumption than the reference model and may be applied to both small and large organizations. As a result of decreased computational complexity, the network's overall energy usage decreased as well. The improvement in scalability in comparison to online payment systems like PayPal and Visa is the current focus of study. In this study, we suggested a methodology to investigate the number of transactions per second and reduce the network's energy consumption in order to improve scalability. As a result of decreased computational complexity, the network's overall energy usage decreased as well.

REFERENCES

1. A. Kaudare, M. Hazra, A. Shelar and M. Sabnis, "Implementing Electronic Voting System With Blockchain Technology," 2020 International Conference for Emerging Technology (INCET), 2020, pp. 1-9, doi: 10.1109/INCET49848.2020.9154116.
2. T. M. Roopak and R. Sumathi, "Electronic Voting based on Virtual ID of Aadhar using Blockchain Technology," 2020 2nd International Conference on Innovative Mechanisms for Industry Applications (ICIMIA), 2020, pp. 71-75, doi: 10.1109/ICIMIA48430.2020.9074942.
3. S. K. Vivek, R. S. Yashank, Y. Prashanth, N. Yashas and M. Namratha, "E-Voting Systems using Blockchain: An Exploratory Literature Survey," 2020 Second International Conference on Inventive Research in Computing Applications (ICIRCA), 2020, pp. 890-895, doi: 10.1109/ICIRCA48905.2020.9183185.
4. E. Febriyanto, Triyono, N. Rahayu, K. Pangaribuan and P. A. Sunarya, "Using Blockchain Data Security Management for E-Voting Systems," 2020 8th International Conference on Cyber and IT Service Management (CITSM), 2020, pp. 1-4, doi: 10.1109/CITSM50537.2020.9268847.
5. S. T. Alvi, M. N. Uddin and L. Islam, "Digital Voting: A Blockchain-based E-Voting System using Biohash and Smart Contract," 2020 Third International Conference on Smart Systems and Inventive Technology (ICSSIT), 2020, pp. 228-233, doi: 10.1109/ICSSIT48917.2020.9214250.
6. L. P. K., M. N. K. Reddy and L. M. Manohar Reddy, "An Integrated and Robust Evoting Application Using Private Blockchain," 2020 4th International Conference on Trends in Electronics and Informatics (ICOEI)(48184), 2020, pp. 842-846, doi: 10.1109/ICOEI48184.2020.9142999.
7. Y. Abuidris, A. Hassan, A. Hadabi and I. Elfadul, "Risks and Opportunities of Blockchain Based on E-Voting Systems," 2019 16th International Computer Conference on Wavelet Active Media Technology and Information Processing, 2019, pp. 365-368, doi: 10.1109/ICCWAMTIP47768.2019.9067529.
8. Y. Pang, "A New Consensus Protocol for Blockchain Interoperability Architecture," in IEEE Access, vol. 8, pp. 153719-153730, 2020, doi: 10.1109/ACCESS.2020.3017549.
9. Jabbar, S., Lloyd, H., Hammoudeh, M. et al. Blockchain-enabled supply chain: analysis, challenges, and future directions. Multimedia Systems (2020). https://doi.org/10.1007/s00530-020-00687-0
10. Abuidris, Y., Kumar, R., Yang, T. and Onginjo, J. (2021), Secure large-scale E-voting system based on blockchain contract using a hybrid consensus model combined with sharding. ETRI Journal, 43: 357-370. https://doi.org/10.4218/etrij.2019-0362
11. Ahmed, Md & Shamrat, F.M. & Ali, Md. Asraf & Mia, Md Rajib & Khatun, Mst.Arifa. (2020). The Future of Electronic Voting System Using Blockchain. International Journal of Scientific & Technology Research. 09. 4131-4134.
12. The Ballot is Busted Before the Blockchain: A Security Analysis of Voatz, the First Internet Voting Application Used in U.S. Federal Elections, https://www.usenix.org/conference/usenixsecurity20/presentation/specter
13. I. A. Srivastava, B. Saini, S. Phansalkar and S. Patwe, "Secure and Transparent Election System for India using Block chain Technology," 2018 IEEE Punecon, 2018, pp. 1-6, doi: 10.1109/PUNECON.2018.8745404.
14. N. A. J. Al-Habeeb, N. Goga, H. A. Ali and S. M. S. Al-Gayar, "A New M-voting System for COVID-19 Special Situation in Iraq," 2020 International Conference on

e-Health and Bioengineering (EHB), 2020, pp. 1-4, doi: 10.1109/EHB50910.2020.9280275.

15. Bellini E., Ceravolo P., Bellini A., Damiani E. (2020) Designing Process-Centric Blockchain-Based Architectures: A Case Study in e-voting as a Service. In: Ceravolo P., van Keulen M., Gómez-López M. (eds) Data-Driven Process Discovery and Analysis. SIMPDA 2018, SIMPDA 2019. Lecture Notes in Business Information Processing, vol 379. Springer, Cham. https://doi.org/10.1007/978-3-030-46633-6_1
16. Zhou, Y., Liu, Y., Jiang, C. et al. An improved FOO voting scheme using blockchain. Int. J. Inf. Secur. 19, 303–310 (2020). https://doi.org/10.1007/s10207-019-00457-8
17. Li, C., Xiao, J., Dai, X. et al. AMVchain: authority management mechanism on blockchain-based voting systems. Peer-to-Peer Netw. Appl. (2021). https://doi.org/10.1007/s12083-021-01100-x
18. Ruhi Taş, Ömer Özgür Tanrıöver, "A Manipulation Prevention Model for Blockchain-Based E-Voting Systems", Security and Communication Networks, vol. 2021, Article ID 6673691, 16 pages, 2021. https://doi.org/10.1155/2021/6673691
19. PoV: An Efficient Voting-Based Consensus Algorithm for Consortium Blockchains, https://www.frontiersin.org/articles/10.3389/fbloc.2020.00011/full
20. Taş R, Tanrıöver ÖÖ. A Systematic Review of Challenges and Opportunities of Blockchain for E-Voting. Symmetry. 2020; 12(8):1328. https://doi.org/10.3390/sym12081328
21. Daramola, Olawande & Thebus, Darren. (2020). Architecture-Centric Evaluation of Blockchain-Based Smart Contract E-Voting for National Elections. Informatics. 7. 16. 10.3390/informatics7020016.
22. Fatrah, Aicha & El Kafhali, Said & Salah, Khaled & Haqiq, Abdelkrim. (2020). Transparent Blockchain-Based Voting System: Guide to Massive Deployments. 10.1007/978-3-030-58669-0_22.
23. A. Singh and K. Chatterjee, "SecEVS : Secure Electronic Voting System Using Blockchain Technology," 2018 International Conference on Computing, Power and Communication Technologies (GUCON), 2018, pp. 863-867, doi: 10.1109/GUCON.2018.8675008.
24. S. Shukla, A. N. Thasmiya, D. O. Shashank and H. R. Mamatha, "Online Voting Application Using Ethereum Blockchain," 2018 International Conference on Advances in Computing, Communications and Informatics (ICACCI), 2018, pp. 873-880, doi: 10.1109/ICACCI.2018.8554652.
25. C. K. Adiputra, R. Hjort and H. Sato, "A Proposal of Blockchain-Based Electronic Voting System," 2018 Second World Conference on Smart Trends in Systems, Security and Sustainability (WorldS4), 2018, pp. 22-27, doi: 10.1109/WorldS4.2018.8611593.
26. Yi, Haibo. (2019). Securing e-voting based on blockchain in P2P network. EURASIP Journal on Wireless Communications and Networking. 2019. 10.1186/s13638-019-1473-6.
27. Yu B. et al. (2018) Platform-Independent Secure Blockchain-Based Voting System. In: Chen L., Manulis M., Schneider S. (eds) Information Security. ISC 2018. Lecture Notes in Computer Science, vol 11060. Springer, Cham. https://doi.org/10.1007/978-3-319-99136-8_20
28. Sun, X., Wang, Q., Kulicki, P. et al. A Simple Voting Protocol on Quantum Blockchain. Int J Theor Phys 58, 275–281 (2019). https://doi.org/10.1007/s10773-018-3929-6
29. Pawade, Dipti & Sakhapara, Avani & Badgujar, Aishwarya & Adepu, Divya & Andrade, Melvita. (2020). Secure Online Voting System Using Biometric and Blockchain. 10.1007/978-981-32-9949-8_7.
30. Barański, Stanisław & Szymanski, Julian & Sobecki, Andrzej & Gil, David & Mora, Higinio. (2020). Practical I-Voting on Stellar Blockchain. Applied Sciences. 2. 10.3390/app10217606.
31. Chaieb, M, Yousfi, S, Lafourcade, P, Robbana, R. Design and practical implementation of verify-your-vote protocol. Concurrency Computat Pract Exper. 2021; 33:e5813. https://doi.org/10.1002/cpe.5813
32. Kashif Mehboob Khana , Junaid Arshadb , Muhammad Mubashir Khanc "Investigating Performance Constraints for Blockchain Based Secure e-Voting System"Elsevier 2019 https://doi.org/10.1016/j.future.2019.11.005

Design and Implementation of Caretaker Robotic System for Hospitals

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ABSTRACT

Elderly and physically feeble people would like to lead an independent and quality life. Some physical or mental assistance may help improve their lifestyle. Today, young people/nurses cannot offer them the attention they require for their engagements, which has a massive impact on their health. All over the world, healthcare is seen as a critical problem. The Caretaker Robot for Hospital is designed to regulate the health care management system. The robot will become an assistant to accompany patients during their access to the care service, guarantee personalized care adapted to the user, and optimize the health professional's work without constant supervision. An android application development will enable the user to control the robot to conduct various activities like time monitoring of medications, food, books/magazines, and signals in emergencies. A medicine reminder box interfaced with the Arduino will be kept next to the patient's bed to remind patients to take their medications. The project's primary goal is to automate hospital work in order to relieve stress on medical assistance and professionals providing medical care while also enhancing system intelligence.

KEYWORDS: *Raspberry pi, Arduino UNO, Robot, Android, Medicine reminder box, Client-server communication.*

INTRODUCTION

A health care management system is an organisation of people, resources, and institutions that provide health care services to the people. Its main goal is to provide good health. But it is a very difficult task to monitor and to look after each and every patient's requirements continuously. To reduce the workload of healthcare system workers such as nurses, this project introduces a Caretaker Robot for Hospitals which will deliver the required utilities to the patient, and also designed a Medicine Reminder Box (MRB) that will remind the patient to take the medicine at the prescribed time. The robot is designed in such a way that it follows a predefined path to reach the exact bed position in the hospital. A mobile application is provided to the patient (or relatives of the patient) through which the patient can convey messages for utilities required.

Based on the request, the robot travels to the utility counter. After receiving the utilities, the robot will travel to the designated bed and give a speech signal to pick up the utility. After staying for a short period of time, the robot travels back to its resting position.

BLOCK DIAGRAM

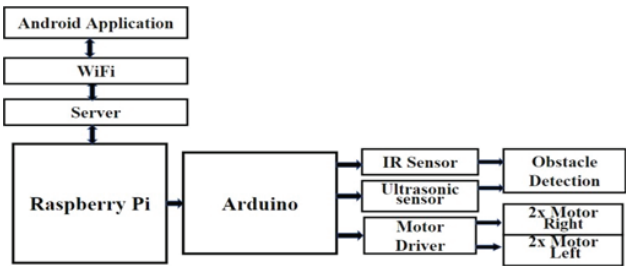

Fig. 1. Block Diagram for Robot Movement

As seen from Fig. 1., the basic mechanism of the caretaker robot for hospital system is to deliver and inform patience of the utilities following a specified path. The system all over performs tasks in a pre-loaded sequence. The patient is provided with a mobile app with the help of which they can convey their message to a robot as per the services to be requested along with the bed number. The medicine box in Fig. 2. will be

kept near the patient bed, interfaced with the Arduino. At the specific medication time of the patient, the LED attached to the box will glow, which indicates the patient to take medicine at that time. The Robot will give instructions to the patient to take medication. Based on the patient's requirement, the robot travels to the utility counter and the distance to be travelled is already set in the algorithm.

After the receiver of utilities, the robot using the time-based algorithm proceeds to the ward. On arrival at the designated bed, stays there for a short period expecting the patient to collect the utilities. After that period, it returns to the initial designation of rest. While traveling from source to destination, if it encounters an obstacle in its path, it signals the obstacle to move from its way.

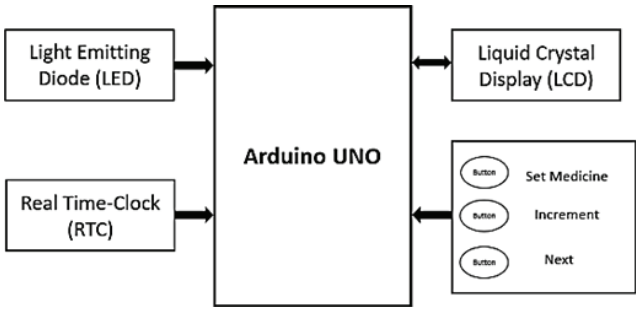

Fig. 2. Block Diagram for Medicine Reminder Box

In hospitals, there are a number of patients, making it challenging to remember each one to take their medication on time. Traditional methods need human efforts to remind them to take their medications on time. The digital era does not follow this, and it may employ machines to accomplish so.

Medicine Reminder Box can be utilized by patients at home, doctors in hospitals, and in a variety of different settings. Medicine Reminder using Arduino that reminds patients to take their medications 1 or 2 or 3 times each day. Push buttons are used to pick a time slot. It also displays the current Date and Time.

ROBOT CONTROL

Mobile Application - The mobile application contains a simplified front-end for the user that is easy to use. The mobile application (app) enables the user to control the robot and conduct various activities like ordering food, books/magazines, and other requests. The mobile app features 7 screens in total(sign-in with user name and password, registration page, menu page with selection of order type, selection of medicine/ book/magazine, pending order page, order delivery, order confirmation, order delivered).The mobile app was created in Java using Android Studio 3.1.3.

The registration page allows admitted patients and medical assistance to sign up for the application. It consists of inputting the user-name, complete name, password, confirm password, selecting whether it is for a patient or an assistant and selecting the bed number to be assigned.

After a successful sign-in, the patient or assistant will be redirected to the navigation page. The delivery order section shows the status of the order being placed. The order selection page enables the patient to add an order to the list. The pending order page shows the pending order to be delivered. After placing the order on the bot, the assistant can remove the order from the list by left-clicking on the order.

Fig. 3. Mobile Application

Database management - The database idea was employed to conduct the process of utilities data extraction. First, a database with a list of all the books, medicines, foods,

and their relevant data was built using mySQL. The hospital table holds all hospital-related data, such as the ward number, bed number, and patient login. The login table retains all data entered by the patient and assistant during login. The utilities data extraction is done from the database, which contains all of the data. Each object is identified by a unique accession number. When a user orders an item, the order details database is updated to reflect which patients have orders for which items. The database also includes ack by, ack on, and rec on, which are updated based on the delivery status.

Design of Robot - The base, which has four wheels for mobility of the robot, as well as vertical chambers for storing utilities. The chassis was developed and cut from a Bakelite sheet and aluminum rods of measuring 40 x 35 cm, taking into account the distance between the two tiers and its turning radius. Four DC motors are mounted. to the base, where the wheels are attached. The vertical column is built of aluminum channels and stands 3 feet tall. This motion is taken into account when utilities must be transported from the utilities contour to the patient bed.

Fig. 4. Final Model of the Caretaker Robot

Robot Movement - Initially, it has to run the client program on the Raspberry Pi, which will inform the robot that it is ready to listen for requests and return bed 0, after which the robot will travel to the specific bed based on the request from the server. The Arduino is used to control the movement of the DC motor. The distance to be travelled is predefined in an algorithm in the form of time(sec). If the robot has to deliver books to bed 1, it will drive straight for 20 seconds, then turn left for 9 seconds, continue for 10 seconds, turn right for 5 seconds, stops expecting the patient to take medicine and then it will return to its initial location. The same goes for all of the beds.

WiFi Data transfer - The server sends the bed number and location to the raspberry pi, and the raspberry pi sends it back to the server. The location is used to locate the bed, so that the robot receives the bed number and proceeds to the bed's location.

Order Confirmation and Delivery - The raspberry pi and the android app will communicate via the host server. The robot is in continual connection with the server, which tells it what action to take. The robot will travel in the direction specified by the server. As the patient places the order on the application, the medical assistant will confirm the order using the android application. Along with the order, the medical assistant will receive the patient's bed number, and the server will notify the robot that the order is ready to be delivered.

The entire process can be depicted in the form of a following algorithm:

Start

a. Initialization of the client program on Raspberry Pi.

Robot Ready

a. Raspberry Pi informs the robot is ready to listen for requests.

Receive Bed Request

a. Server sends bed number and location to Raspberry Pi.

Movement Control

a. Raspberry Pi communicates with Arduino to control DC motor.

Predefined Movement Algorithm:

a. Bed 1:

i. Drive straight for 20 seconds.

ii. Turn left for 9 seconds.

iii. Continue straight for 10 seconds.

iv. Turn right for 5 seconds.

v. Stop at bed 1.

b. Other Beds:

i. Similar predefined movement patterns.

Patient Interaction

a. Robot stops at the bed, expecting patient interaction (e.g., taking medicine).

Return to Initial Location

a. Robot returns to its initial location after delivery.

WiFi Data Transfer

a. Bed number and location sent from server to Raspberry Pi.

b. Raspberry Pi sends confirmation back to server.

Order Confirmation and Delivery

a. Patient places order on the Android app.

b. Medical assistant confirms order on the app.

c. Server notifies robot of the confirmed order and bed number.

d. Robot proceeds to the specified bed for delivery.

End

MEDICINE REMINDER BOX

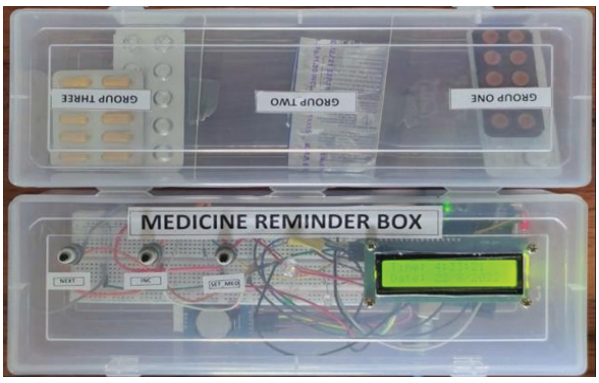

Fig. 5. Medicine Reminder Box

The medicine reminder box will be kept near the patient's bed, interfaced with the Arduino. At the specific medication time of the patient, the LED attached to the box will glow, which indicates the patient should take medicine at that time. A real-time clock displays the time on a 16 x 2 LCD when the medicine reminder box is turned on. To set the medication time, press the "set med" button. After pressing this button, the LCD displays the set medicine reminder time for time 1. Than select the time for medication by pressing the INC and NEXT buttons, which are connected to pin 2 and 7 respectively of the Arduino.

CONCLUSION

The Caretaker Robot for Hospital has been implemented to reduce the considerable number of medical mistakes and improper dosage intakes while also effectively increasing the convenience of healthcare assistance. The caretaker robot would definitely be one of the remedies for the negligence issue. The design of a unique chassis used to manoeuvre the robot is what makes the proposed work novel. The Robot receives input from the user via a mobile application and sends it to the raspberry pi through a server when the robot has finished the entire procedure. The database will then be updated and informed that the task was successfully completed.

All of this is implemented successfully using real-time data. The proposed model can also be further developed for other applications such as elderly person or patient care at home, as well as delivery in malls and hotels.

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REFERENCES

1. V. Vishal, S. Gangopadhyay, and D. Vivek, "Carebot: The automated caretaker system," in 2017 International

Conference on Smart Technologies for Smart Nation (SmartTechCon), 2017, pp. 1333–1338.

2. R. K. Dwibedi, A. Muduli, P. Vignesh, R. Mohankumar, and S. V. Thukalan, "Design and implementation of patient monitoring robot in hospitals," in AIP Conference Proceedings, vol. 2405, no. 1. AIP Publishing LLC, 2022, p. 020011.
3. D. Punetha, N. Kumar, and V. Mehta, "Development and applications of line following robot based health care management system,".
4. A. Malhotra and B. Bhardwaj, "Health monitoring and immediate assistance smart bot for elderly people using slam," in 2018 Fourteenth International Conference on Information Processing (ICINPRO), 2018, pp. 1–5.
5. S. Yu Hing, C. Chi Hung, L. Kam Fat, and Jonathan, "Smart elderly care robot," in 2020 IEEE 2nd International Workshop on System Biology and Biomedical Systems (SBBS), 2020, pp. 1–4.
6. M. A. Hossain, M. E. Hossain, M. J. Uddin Qureshi, M. Abu Sayeed, M. A. Uddin, U. Afififa Jinan, and M. A. Hossain, "Design and implementation of an iot based medical assistant robot (aido-bot)," in 2020 IEEE International Women in Engineering (WIE) Conference on Electrical and Computer Engineering (WIECON-ECE), 2020, pp. 17–20.
7. San Hlaing, Ni Ni and San Naing, San, "Alarm System for Medicine Reminder Based on Microcontroller" in 2019.
8. Bhati, Sanjay and Soni, Harshid and Zala, Vijayrajsinh and Vyas, Parth and Sharma, Yash, "Smart medicine reminder box", in 2017 IJSTE- International Journal of Science Technology & Engineering, vol.3, no.10, pp.172–177.
9. Persson, Marcus and Redmalm, David and Iversen, Clara," Caregivers' use of robots and their effffect on work environment–a scoping review", in 2021 Journal of technology in human services, pp.1–27.
10. G¨ule¸ci, Mehmetcan and Orhun, Murat,"Android based WI-FI controlled robot using Raspberry Pi", in 2017 International Conference on Computer Science and Engineering (UBMK), pp.978–982.
11. Butter, Maurits and Rensma, Arjan and Kalisingh, Sandy and Schoone, Marian and Leis, Miriam and Gelderblom, Gert Jan and Cremers, Ger and Kortekaas, Willem and Thielmann, Axel and Cuhls, Kerstin and others, "Robotics for healthcare" in 2008.
12. Vishal, V and Gangopadhyay, Sayantan and Vivek, D, "CareBot: The automated caretaker system", in 2017 International Conference On Smart Technologies For Smart Nation (SmartTechCon), pp.1333-1338
13. Z. Rebolledo-Nandi, A. Chávez-Olivera, R. E. Cuevas-Valencia, A. Alarcón-Paredes and G. A. Alonso, "Design of a versatile low cost mobile health care monitoring system using an android application," Pan American Health Care Exchanges (PAHCE), Santiago, Chile, 2015, pp. 1-4.
14. Hideki Yamamoto, Hiroshi Endo, Koichi Kitajima, Shingo Ohashi, Isao Kondoh and Michiyoshi Kuwahara, "A Health Care Robot For Patients", IEEE International Workshop on Intelligent Robots and Systems.
15. Daniel Hernandez Garcia, Pablo G. Esteban, Hee Rin Lee, Marta Romeo, Emmanuel Senft, Erik Billing, "Social Robots in Therapy and Care", in 2019.

Experimental Investigation on the Performance of Deep Learning and Machine Learning Algorithms for Gujarati Text Dataset

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ABSTRACT

As increasing multi-linguistic text data on web, need to be analyzed with different machine learning methods. Gujarati language is also widely used language on many web platforms and classification of Gujarati text data is less explored in literature. Now a days, other well-known techniques are used for text classification and it is deep learning methods. Till date, Deep learning methods are not applied for Gujarati text dataset. This paper considered traditional ML and advanced methods, DL on Gujarati datasets. This paper explained and compared traditional and deep learning-based classification methods for exist Gujarati news text dataset and another Gujarati e-books text dataset, which is collected, cleaned by myself for implementation. This paper shows that deep learning methods are enhanced accuracy of classification methods compared to traditional methods.

KEYWORDS: *Text classification, Gujarati text data, Deep learning, Machine learning, Pre-processing.*

INTRODUCTION

Vast number of documents, books, news, tweets etc. posted on web daily basis; need to be automatically classifying them. Special cases can be considered as this text data is available in Indian languages. These languages are not widely used all over the world or India but more important for that region's people in India to identify, classify or predict decisions based on those local languages [1-3]. Gujarati, Punjabi, Marathi etc. Indian languages text data has been manually classified is a time consuming and error enabled process. Automatically classification processes reduce human efforts, increase speed and are less error worthy. In literature, not that much work has been done on classification using deep learning models for Gujarati language text data. Main objective of this paper is to enhance the performance of classifiers for Gujarati text data using deep learning models. This paper mainly focuses on comparisons of standard machine learning classification algorithms and deep learning algorithms. For experimental purposes, we have used one existing dataset-gujarati news headlines (short sentence sized data) and another is gujarati books full sized text documents type of data which is collected and cleaned by the author itself. In literature, Gujarati books automatic classification is not focused as the survey proves that full text document classification accuracy is high compared to short book title-based classification [4,25].

About Gujarati Language

Gujarati language is a native language for Gujarat state and union territory of Dadra Nagar Haveli, Diu and Daman. As per 2011 report, Gujarati language is 6th most widely used language in India and as per 2007 report, it is the 26th most spoken language in the world [4,22]. Gujarati is officially recognized in the Indian constitution and is spoken by more than 46 million people [5,23]. Half of the million people outside of India (Tanzania, Uganda, Pakistan, Kenya and Zambia, Canada, USA etc.), where the Gujarati people live, speak gujarati. Gujarati language belongs to the Indo-Aryan language of the Indo-European language family

and it is also closely related to Indian Hindi language [22,23]. Gujarati language has alphabets like Vyanjan (consonants) and Swar (Vowels). Gujarati numbers are also represented differently as shown in the figure-1 [22].

LITERATURE

In a literature, many gujarati datasets are used for general text processing like machine learning and natural language processing. For example, gujarati speech recognition, gujarati handwritten character recognition, gujarati poetry dataset used for text generation, poetry analysis and style transfer, gujarati language identification in case of multilingual text processing, gujarati sentiment analysis, gujarati Wikipedia and news dataset etc. paper discussed following research, done in literature.

Chirag Patel and Karthik Gali have used CRF for part of speech (POS) tagging for Gujarati data. Authors used training data with 10,000 words and manually tagged 600 sentences and test data with 5000 sentences with 5000 words. Authors get 92% accuracy for tagging gujarati sentences [3]. Rajnish M. Rakholia and Jatinderkumar R. Saini have used 1680 Gujarati documents with six categories like sports, health, entertainment, business, astrology and spiritual. Authors used the NB classifier for classification with TFIDF as feature selection method on and got accuracy around 75.74% and 88.96% without and with features selection approach. Authors also tried with different cross-validation folding like 10-fold, 8-fold, 6-fold, 4-fold,2-fold. A 2-fold CV proved better for a given dataset [5].

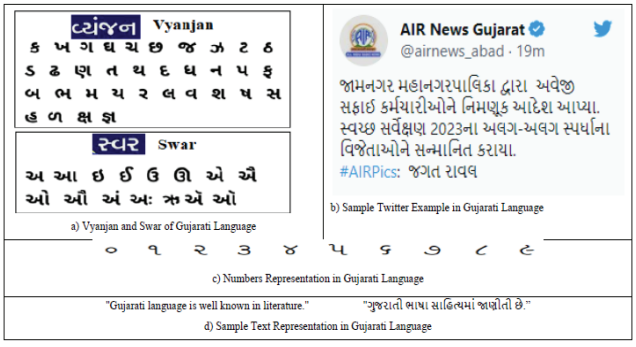

Fig 1. Gujarati Language Properties [22]

Tripti Dodiya, Dr. Ali Yawar Reha have used medical english sentences dataset and converted to gujarati sentences dataset for experiments. Author tried to generate TFIDF value for each keyword as output. Authors mainly focus on data representation, not on stemming, stop word removal or classification tasks [6]. Jatin and Jitender [7] have developed a model to dynamically generate n-gram idioms based on Diacritics and Suffix-based Rules so they are identified or properly searched in a given dataset. Authors used 3240 Gujarati idioms which have their 7050 different idiom forms. Authors generated 15 rules for generating idioms properly. This is helpful for the machine translation system so Gujarati idioms can be converted to any other language.

Authors [8] introduced and suggested complexity score method for developing a readability test method for natural language processing tasks for the Gujarati language. Authors [4,9] introduced Hidden Markov Model (HMM) based named entity recognization for gujarati text. Authors work for tagging of gujarati words like name, location, organization, numbers and others.

Parita et. al. [13] try to classify gujarati film review using kNN and NB with BOW and TFIDF. Authors proved that TFIDF and NB is better suitable for film review dataset. NB gives 87.14% with TFIDF.

Juhi et. al. introduced own gujarati stemming method after studying verb, adverb etc. of gujarati language and result is improved shown sample in figure-2 [10].

Word	Stem	Suffix
શહેરી	શહેર	ી
વિસ્તારોમાં	વિસ્તાર	ોમાં
ભાજપનો	ભાજપ	નો

Fig 2. Gujarati Stemming Example [10]

MOTIVATION

In literature, researcher used Naive Bayes, Support Vector Machine etc. ML algorithms and convolution neural network DL algorithm for gujarati tweet classification. Support vector machine is used for gujarati news headline classification. These much research has been carried out in literature but now a days, many deep learning variety of algorithms introduced as well as rest of machine learning algorithms are not used

compared for gujarati text data specifically gujarati books classification. for testing purpose, this paper used gujarati text book dataset which is self-collected and preprocessed [26] and another is gujarati news headlines dataset [27]. This paper is compared all well-known text classification algorithms and deep learning algorithms. Next section gives brief introduction about all classification algorithms.

MACHINE LEARNING ALGORITHMS [16,22,24]

Here, we have discussed some overviews of machine learning algorithms used for text classification purpose.

Logistic Regression

It is supervised machine learning method and statistical based model for classification. It is used for predicting binary classes. Logistic function is a type of sigmoid curve. Logistic regression estimates the relationship between independent and dependent variables. It is easy to understand compared to too complex deep learning models.

Support Vector Machine

It is popular model and effective for classification task on specific non-linearly separable dataset. SVM find the optimal hyper plane and closest data points as support vectors by maximizing the margins between them. The SVM algorithm can use different kernel functions such as linear, polynomial, or radial basis function (RBF) to transform the input features into a higher dimensional space where the data becomes separable. Overall, SVMs can be a good choice for Gujarati text classification tasks that involve non-linearly separable data. It can handle high feature spaces well as text data has high dimensional data.

Naïve Bayes

It is based on naïve bayes theorem which is probability of hypothesis given the evidence, works by computing the probability of each feature given the class label, and then combining these probabilities using Bayes theorem to compute the probability of the class label given the features. Naive Bayes assumes that the features are conditionally independent given the class label, which leads to the assumption that the features are independent of each other.

Random Forest

RF is a type of ensemble learning algorithm. It combines multiple decision trees to improve the classification performance. Each decision tree is trained separately as it helpful to avoid over fitting problem and improve generalized performance. During predicting phase, all trees' predictions are combined overall. Random Forest can be a good choice for Gujarati text classification tasks that involve non-linearly separable data and complex relationships between features. Random Forest is also relatively simple and easy to interpret compared to more complex models.

Gradient Boosting

It is also an ensemble learning algorithm, like Random Forest, but it works by combining multiple weak models in a sequential manner to improve the classification performance. Gradient boosting works by sequentially adding multiple weak models, such as decision trees, to the ensemble, and each new model is trained to correct the errors of the previous models. During the training phase, the model tries to minimize a loss function, such as the binary cross-entropy or mean squared error, by adjusting the weights of the weak models. Gradient Boosting is also relatively robust to overfitting, compared to other ensemble learning algorithms and it can handle large feature spaces well.

AdaBoost

AdaBoost (Adaptive Boosting) is a machine learning algorithm that can be used for Gujarati text classification. This ensemble learning algorithm like Gradient Boosting and Random Forest works by combining multiple weak models in a weighted manner to improve the classification performance. AdaBoost works by sequentially adding multiple weak models, such as decision stumps (i.e., simple decision trees with only one split), to the ensemble. Finally, AdaBoost can be a good choice for Gujarati text classification tasks that involve simple relationships between features and linearly separable data. AdaBoost is also relatively simple and easy to implement DL models. However, this method can be sensitive to noisy data and outliers.

Ensemble

Ensemble learning is a powerful approach for Gujarati text classification that combines multiple machine

learning models to improve the overall classification performance. This method works by aggregating the predictions of multiple models, which can help to reduce the bias and variance of individual models. Some popular ensemble learning methods for Gujarati text classification are bagging, random forest, boosting, adaboost, gradient boosting. Ensemble learning can be a good as it involves complex relationships between features and non-linearly separable data. Ensemble learning can also improve the robustness and generalization performance of individual models, and it can handle large feature spaces well.

DEEP LEARNING ALGORITHMS [17-21]

Deep Neural Network (DNN)

Deep Neural Network is collection of neurons in multi-layered form. Internally mathematical calculation performed for final output. Internal mapping is learned from data by adopting weight value using back propagation. DNN is a feed forward multilayer or multilayer collection of artificial neural networks (ANN) [17].The output layer neurons define the decision as a class label for text data. In DNN, multi-class problem is represented with multi neurons as output. It defines one neuron for binary classification. DNN uses the standard back-propagation algorithm, sigmoid as activation function and softmax as output layer for multi-class classification.

LSTM

Long Short-Term Memory (LSTM) is a subtype of RNN. It includes long term dependency in a more effective way compared to the basic RNNs [24], which useful to overcome the vanishing gradient problem.

One good reason to use LSTM is that it is effective in memorizing important information. If we look and other non-neural network classification techniques they are trained on multiple word as separate inputs that are just word having no actual meaning as a sentence, and while predicting the class it will give the output according to statistics and not according to meaning. That means, every single word is classified into one of the categories.

Gated Recurrent Unit (GRU)

Gated Recurrent Unit (GRU) is a gating mechanism for RNN which was introduced by authors J. Chung et al. and other authors K.Cho et al.. GRU is a simplified variant of the LSTM architecture, but there are differences as follows: GRU contains two gates and does not possess any internal memory and finally, a second non-linearity is not applied [22].

BERT (Bidirectional Encoder Representations from Transformers)

It is an open-sourced NLP pre-training model developed by researchers at Google in 2018.BERT makes use of the Transformer, an attention mechanism that learns contextual relations between words in a text. In its vanilla form, Transformer includes two separate mechanisms- an encoder that reads the text input and a decoder that produces a prediction for the task. Since BERT's goal is to generate a language model, only the encoder mechanism is necessary. The detailed implementations of Transformer are described in a paper by Google. As opposed to directional models, which generally read the input text sequentially (left-to-right or right-to-left), the Transformer encoder which is used in Bert reads the entire input text or words sequence at once. That is the reason it is considered bidirectional

Convolutional Neural Networks (CNN)

Convolutional Neural Networks (CNN) is used for hierarchical document classification. CNN initially considered that it is made for image processing but now days used for text classification. In image processing, an image tensor is convolved with a set of kernels of size n by n. These layers are called feature maps. It can be stacked to provide multiple filters on the input. Pooling is used to lower the complexity. Different pooling techniques are used to reduce outputs while preserving important features. The most common pooling method is max pooling.

IMPLEMENTATION

Gujarati Text Datasets

Our research paper includes two gujarati datasets. One is self-collected and cleaned dataset: Gujarati E-books [27] and another dataset is gujarati news headlines data [26] downloaded from kaggle global data science community platform. E-book dataset has 10,000 samples and two classes: વાનગી and આધ્યાત્મિક વાર્તાઓ.

News headlines dataset has total 6587 samples/books data which have 2905 samples for entertainment class, 2331 samples for business class, 1351 samples for technology. Among these whole dataset/samples, 4610 samples are used for training and 1977 samples used for testing/validation purpose. This dataset has 3836 words/dimensions after preprocessing steps.

Gujarati text dataset is also need to be pre-processed as English dataset for data classification purpose. Our research work includes basic pre-processing steps as tokenization, stop word removal including suffix and prefix removal, stemming word to vector data representation using TF-IDF method and finally, this dataset used for classification. Following is an example of suffix and prefix, stop words list in gujarati language [10-13].

```
Suffixes=['નાં','ના','ની','નો','નું','ને','થી','માં
','એ','ઓ','ે','તા','તી','વા','મા']
prefixes = ['અ']
stop_words=['હે','છે','જેવા','લ્યો','કે']
```

Sample gujarati news headline:
"મોદી સરકાર 1 ફેબ્રુઆરીએ વચગાળાનું બજેટ રજૂ કરશે, આ જાહેરાતો થઇ શકે"
After removal of prefix and suffix:
"મોદ સરકાર 1 ફેબ્રુઆરી વચગાળા બજેટ રજૂ કરશ,આ જાહેરાત થઇ શક"
After tokenization:
['મોદ', 'સરકાર', 'ફેબ્રુઆરી', 'વચગાળા', 'બજેટ', 'રજૂ', 'કરશ', ',', 'આ', 'જાહેરાત', 'થઇ', 'શક']
After punctuation removal:
['મોદ', 'સરકાર', 'ફેબ્રુઆરી', 'વચગાળા', 'બજેટ', 'રજૂ', 'કરશ','જાહેરાત', 'થઇ', 'શક']

In pre-processing, stemming of word is a helpful in gujarati text as discussed in the paper [11]. They have explained a rule based stemming method using gujarati dictionary. There are several Gujarati stemming methods available that can be used to derive the root form of a Gujarati word. Here are some of the commonly used Gujarati stemming methods [10-15]:

Porter Stemming Algorithm

This technique is for english generally but it can also be adapted for Gujarati text. This algorithm applies a series of rules to remove suffixes from the word, such as tense, gender, and number markers, to derive the root form of the word.

Remove any possessive suffixes from the word, such as 'નો', 'ની', 'નું', etc. Remove any tense or case markers from the word, such as '-વું', '-યો', '-તો', etc. Remove any plural markers from the word, such as '-ઓ', '-આ', '-એ', etc. Remove any comparative or superlative markers from the word, such as '-તર', '-તમ', etc.
Remove any diminutive suffixes from the word, such as '-ડું', '-ટું', '-ટડું' etc. Remove any derivational suffixes from the word, such as '-કાર', '-કામ', '-વાળું', etc.
Remove any derivational prefixes from the word, such as 'અનેક-', 'અપ-', 'અભિ-', etc. Apply additional rules to handle irregular words and exceptions in the Gujarati language.

Kanshi is a rule-based stemming algorithm specifically designed for the Gujarati language. Lovins algorithm is another popular stemming algorithm used for English text, but it can also be adapted for Gujarati text, used for handling irregular words and exceptions in the Gujarati language. Apply additional rules to handle endings that indicate gender, tense and number like singular, plural. Snowball algorithm that can be applied to multiple languages. Hybrid stemming algorithm combine multiple stemming algorithms to derive the root form of a Gujarati word. These methods can be more accurate than individual stemming algorithms and can handle a wider range of words.

In general, stemming methods for Gujarati text are still evolving, and new methods are being developed to improve the accuracy of the stemming process. The choice of stemming method often depends on the specific task and domain of the text analysis.

RESULT DISCUSSION

To train and evaluate the classification model, we used two gujarati datasets as explained above and used traditional and deep learning classification methods. We executed these algorithms with python 3.9 with ML library and keras library. We have taken some standard parameters values for certain classification algorithm from literature. Figure 3 and 4, shown that ensemble

and then LR, SVM performed better for news headlines dataset and RF performed better for e-books dataset. Figure-5 shows that GRU performed better for news headlines dataset as well as gujarati e-books dataset. Deep learning algorithms are used with Rectified Linear Unit (ReLU) activation function in input layers, sigmoid activation function in output layer and 100 epochs.

CONCLUSION AND FUTURE WORK

Our research work has been carried out to gujarati text data classification using machine learning algorithms and deep learning algorithms. This paper is also discussed basics of gujarati text datasets properties, ML algorithms used for gujarati dataset. Exist gujarati news headline dataset and self-collected, cleaned gujarati e-books dataset are used for algorithms evaluation. Using machine learning algorithms, results have been shown that accuracy of ensemble and then LR, SVM performed better for news headlines dataset and RF performed better for e-books dataset. Using deep learning algorithms, results have been shown that GRU is performed better for both datasets. Compared to machine learning, deep learning algorithm is outperformed. In future, there is need to focus on stemming method to enhance the classifiers' performance.

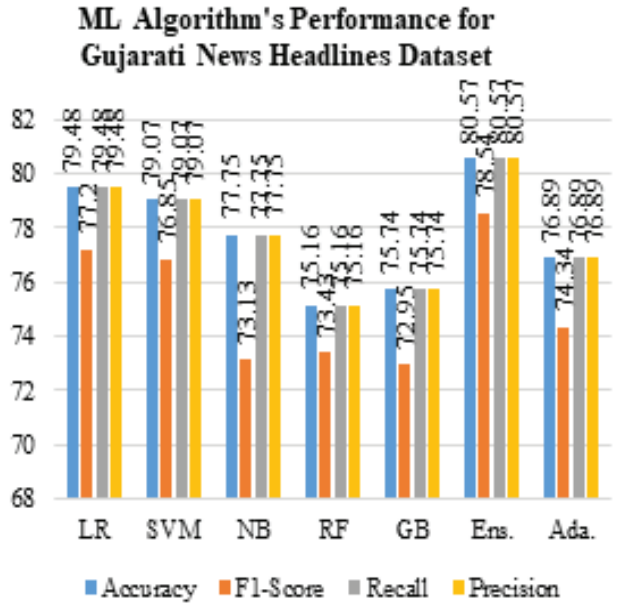

Fig. 3. Chart of Performance Measure for Gujarati News Headlines Dataset using ML algorithms

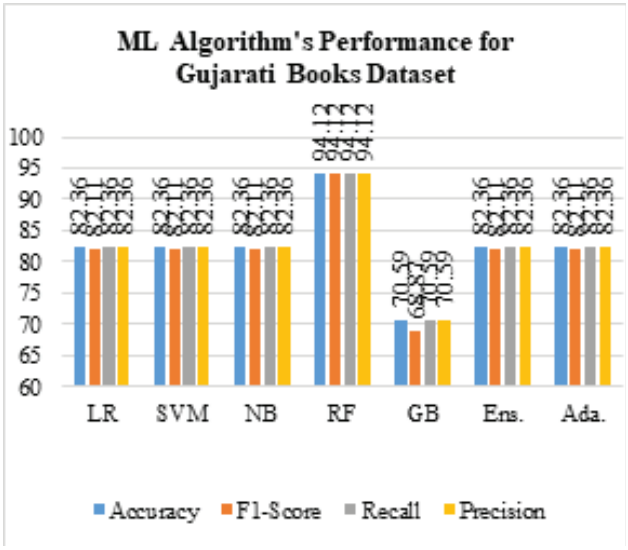

Fig. 4. Chart of Accuracy measure for Gujarati E-Books Dataset using ML algorithms

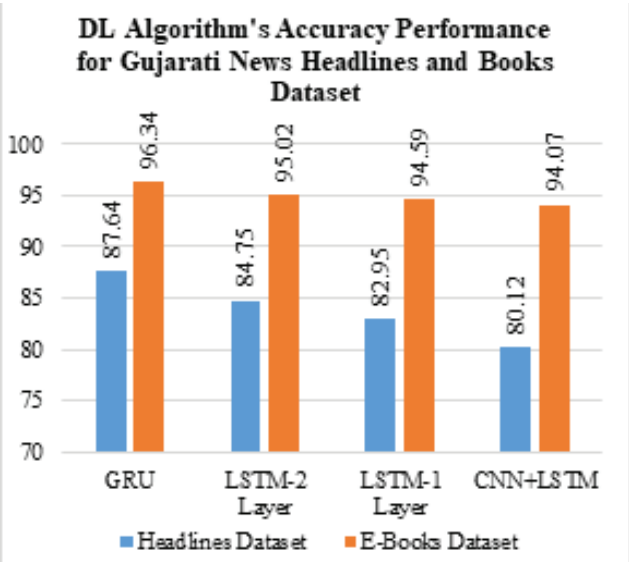

Fig. 5. Chart of Accuracy measure for Gujarati News Headlines Dataset using DL algorithms

REFERENCES

1. Vrunda Joshi and Vipul Vekariya. An Approach to Sentiment Analysis on Gujarati Tweets. Advances in Computational Sciences and Technology. 2017; 10(5): 1487-1493.

2. Chandrakant Patel and Jayesh Patel. Influence of GUJarati STEmmeR in Supervised Learning of Web Page Categorization. International Journal Intelligent Systems and Applications. 2021; 3: 23-34.

3. Chirag Patel and Karthik Gali. Part of Speech Tagging for Gujarati Using Conditional Random Fileds. In Proceeding of IJCNLP 2008 Workshop on NLP for Less Privileged Language. 2008; 117-122.
4. Deepika Kumawat and Vinesh Jain. POS Tagging Approaches: A Comparison, International Journal of Computer Applications. 2015; 118(6): 32-38.
5. Rajnish, Saini and Jatinderkumar. Classification of Gujarati Documents using Naïve Bayes Classifier. Indian Journal of Science and Technology. 2017; 10:1-9.
6. Dodiya Tripti and Ali Yawarreha. Using Term Frequency Inverse Document Frequency to find the Relevance of Words in Gujarati Language. International Journal for Research in Applied Sci. and Engg. Tech.2021; 9(4):378- 381.
7. Modh J C and Saini J R Dynamic. Phrase Generation for Detectionof Idioms of Gujarati Language using Diacritics and Suffix-based Rules. International Journal of Advanced Computer Science and Applications. 2021; 12(7).
8. Modh J C and Saini J R. A Novel Readability Complexity Score for Gujarati Idiomatic Text. International Journal of Advanced Computer Science and Applications. 2022; 13(5):453-459.
9. Vora K, Vasant A and Adhvaryu R. Named entity recognition and classification for Gujarati language. IEEE International Conference on Advances in Computing Communications and Informatics (ICACCI), 2016: 2269-2272.
10. AMETA J, JOSHI N and MATHURI. A Lightweight Stemmer for Gujarati. In Proceedings of 46th Annual Convention of Computer Society of India. 2012; arxiv.1210/1210.5486
11. Patel C D and Patel J M GUJSTER. A rule based stemmer using dictionary approach. International Conference (ICICCT). 2017; 496-499.
12. Chirag Patel and Karthik Gali. Part of Speech Tagging for Gujarati Using Conditional Random Feilds. In Proceeding of IJCNLP-08 Workshop on NLP for Less Privileged Language. 2018;117-122.
13. Parita Shah, Priya Swaminarayan and Maitri Patel. Sentiment Analysis on Film Review in Gujarati Language using Machine Learning. International Journal of Electrical and Computer Engineering.2022; 12(1): 1030-1039.
14. Hu X and Zhang R. Text classification based on machine learning. IEEE International Conference on Artificial Intelligence and Computer Applications. 2022; 911-916.
15. Sheth J and Patel B. Dhiya A stemmer for morphological level analysis of Gujarati language. IEEE 2014 International Conference on Issues and Challenges in Intelligent Computing Techniques. 2014; 151-154.
16. Kowsari, Jafari Meimandi, Heidarysafa, Mendu, Barnes and Brown. Text Classification Algorithms A Survey. MDPI. 2019; 10(4).
17. Köksal Ö and Akgül Ö. A Comparative Text Classification Study with Deep Learning-Based Algorithms. IEEE 9th International Conference on Electrical and Electronics Engineering. 2022; 387-391.
18. Pirana G, Sertbas A and Ensari T. Sentence Classification with Deep Learning Method for Virtual Assistant Applications. IEEE 3rd International Symposium on Multidisciplinary Studies and Innovative Technologies. 2019.
19. Shervin Minaee, Nal Kalchbrenner, Erik Cambria,Narjes Nikzad, Meysam Chenaghlu and Jianfeng Gao. Deep Learning Based Text Classification A Comprehensive Review. arXiv.2021.
20. Rehman S, Irtaza A, Nawaz M and Kibriya H. Text Document Classification Using Deep Learning Techniques. IEEE International Conference (ETECTE). 2022; 1-6.
21. http://uc-r.github.io/feedforward_DNN
22. https://en.wikipedia.org/wiki/Gujarati_language
23. https://www.britannica.com/topic/Gujarati-language
24. Dan Wang, Jibing Gong and Yaxi Song. W-RNN News text classification based on a Weighted RNN. Arxiv.2019.
25. Lukas Kurasinski. Machine Learning explain ability in text classification for Fake News detection. Thesis. 2020.
26. https://www.matrubharti.com/stories/gujarati/cooking-recipe
27. https://www.kaggle.com/datasets/disisbig/gujarati-news-dataset.

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