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Editorial

Technology Integration: Refers to effective use of digital devices and other tools with proper planning for problem solving, deeper learning and understanding of various activities to achieve the targeted goals and objectives. Innovations in artificial intelligence, renewable energy, biomedical engineering, and materials science have transformed industries and improved quality of life. Artificial Intelligence (AI) and Machine Learning (ML), for instance, are revolutionizing how we approach problem-solving across various sectors, from autonomous vehicles to predictive healthcare. Renewable energy technologies are addressing the critical need for sustainable power sources, while breakthroughs in biomedical engineering are paving the way for personalized medicine and advanced prosthetics.

Technology Integration (TI) plays a vital role in the success of digitization. The integration of digital technologies with traditional engineering practices helps to enable more efficient, effective and sustainable solution. The advent of the Internet of Things (IoT) and the continued evolution of smart systems are enabling more efficient and responsive infrastructure, smart cities, and enhanced industrial processes. Moreover, additive manufacturing and 3D printing are not only streamlining production but also opening new avenues for customised components and rapid prototyping.

Technology Integration can be applied in various fields which include education, industry, healthcare, business, public services, environment, personal life, etc. In education sector, technology integration refers to the use of digital tools, software, and online resources to enhance the student learning experience and create interest amongst the students and prepares students for the future.

Nanotechnology is another area with vast potential, offering advancements from drug delivery systems to stronger, lighter materials with enhanced properties. Furthermore, the intersection of biology and engineering, known as synthetic biology, is giving opportunities for bioengineering, including the creation of synthetic organisms designed for specific tasks such as bio-remediation or the production of biofuels.

While implementing Technology Integration, one may come across some challenges like a resistance to switch over to new technologies, lack of a common operating model, digital divide issues, privacy, physical split between digital and IT groups.

Change is essential, cannot be avoided for the growth.

New Delhi **Editor**

30th June 2024

VPM's Maharshi Parshuram College of Engineering

At Post - Velneshwar, Hedvi-Guhagar Road, Tal. Guhagar,
Dist. Ratnagiri (Maharshtra) - 415729

Contents

A Systematic Analysis of the Latest Developments in Organic, Inorganic and Ceramic Corrosion Protection Coatings

Audumbar Patkar*
✉ audumbar.patkar@vpmmpcoe.org

Arun Sargar
✉ arun.sargar@vpmmpcoe.org

Maharshi Parshuram College of Engineering
Velneshwar, Maharashtra

ABSTRACT

Corrosion presents a widespread and expensive challenge that impacts both the economy and the environment. Protective coatings are essential in defending a variety of sectors from its harmful effects. This detailed survey examines the latest progress in protective coatings against corrosion, with a focus on organic, inorganic, and metal-based types. It delves into the basic principles of these coatings and how they act to prevent corrosion. The paper spotlights the latest innovations in organic coatings, including new mixtures, self-repairing features, and the application of nanotechnology. It also reviews advancements in inorganic and ceramic coatings, such as surface enhancement methods and the creation of organic-inorganic composite coatings. The discussion extends to the latest trends in metal coatings, which encompass alloy creation, eco-friendly alternatives, and advanced surface treatments. Methods for assessing coating efficacy and testing, like expedited corrosion trials, are also outlined. The paper illustrates the extensive use of protective coatings across different industries through case studies. It addresses the prospects and challenges in burgeoning fields like sustainable energy and the aerospace industry. In conclusion, the paper highlights the necessity for continuous research and the adoption of sophisticated materials for comprehensive corrosion protection, offering a crucial reference for those engaged in this field and directing future scholarly work.

KEYWORDS *: Corrosion protection, Advancements, Corrosion protection coatings, Ceramic coatings, Organic coatings.*

INTRODUCTION

Corrosion is a natural process primarily affecting metals and occurs due to chemical or electrochemical reactions with the environment, leading to material degradation. Its economic and environmental impacts are substantial, causing significant financial losses and environmental harm, particularly in industries like oil and gas, transportation, construction, and manufacturing. Corrosion-related failures can result in structural damage, equipment malfunction, and environmental pollution, posing safety risks and escalating economic consequences [1]. To combat these challenges, corrosion protection coatings are vital. These coatings act as barriers, preventing or slowing down corrosive processes by inhibiting contact between materials and corrosive agents. They find widespread application across industries such as oil and gas, automotive, construction, marine, and aerospace, protecting assets from corrosion and ensuring operational safety and longevity. Effective corrosion protection strategies are crucial for mitigating economic losses, safety hazards, and environmental degradation [2].

In summary, corrosion protection coatings act as vital defence mechanisms, preserving materials, infrastructure, and ecosystems from corrosive damage. In this review, we will explore recent advancements in corrosion protection coatings and their diverse applications in different industrial sectors.

The objectives include providing an overview of different coatings, reviewing recent advancements in each type, discussing testing methods, highlighting industrial applications, identifying future research avenues, and emphasizing environmental sustainability.

This work aims to enhance understanding, showcase recent progress, and outline future challenges in corrosion protection coatings.

Essentials of Coatings for Corrosion Prevention

Corrosion protection coatings are essential for safeguarding materials, especially metals, against corrosion damage [3].

Types of Coatings

There are three main categories: organic, inorganic, and metallic coatings. Organic coatings create a protective film over the substrate, offering physical protection and strong adhesion [4]. Inorganic coatings, such as ceramics, resist high temperatures and chemical exposure by forming stable oxide layers [5]. Metallic coatings work via sacrificial or barrier mechanisms, corroding preferentially or physically obstructing corrosive agents [6, 7]. Each type offers unique properties, with organics providing barrier protection, inorganics offering resistance, and metallics providing sacrificial protection. Hybrid coatings combine features from both organic and inorganic varieties.

Table 1. Types of corrosion protection coatings

Coating Type	Description
Organic Coatings	Comprising carbon-based polymers, these coatings create a robust barrier against corrosive environments, ensuring effective protection for the substrate.
Inorganic Coatings	Consisting of materials like metal oxides or ceramics, these coatings excel in resisting high temperatures and harsh chemicals, providing durable protection for various applications.
Metallic Coatings	These coatings, including alloy-based variants, offer sacrificial protection by corroding selectively, safeguarding the underlying substrate from corrosion-induced damage.
Ceramic Coatings	Recognized for their exceptional hardness, thermal stability, and resistance to both wear and corrosion, ceramic coatings are ideal for environments requiring robust protective measures.
Hybrid Coatings	By combining elements of organic and inorganic compositions, hybrid coatings achieve a synergistic effect, enhancing corrosion resistance and overall performance for diverse applications.

Mechanism of corrosion protection coatings

Coatings provide corrosion protection through various mechanisms each tailored to counteract specific corrosion challenges.

- Barrier Effect: This mechanism involves creating a physical shield between the substrate and corrosive agents, hindering their diffusion and reducing the corrosion rate [8].
- Sacrificial Protection: Coatings containing metals with higher electrochemical potential corrode sacrificially to protect the substrate [9]. This process selectively degrades the sacrificial layer, preserving the substrate's integrity.
- Self-healing Properties: Some coatings incorporate components capable of autonomously repairing minor damage, ensuring continuous protection even in the presence of defects [10].

These mechanisms collectively demonstrate the multifaceted strategies employed by coatings to combat corrosion, prolonging material integrity and durability. Understanding these mechanisms is vital for effective corrosion management, guiding the selection and application of coatings tailored to specific environmental conditions and protection requirements.

Latest Developments in Organic Coating Technology

Inorganic and ceramic coatings are gaining prominence for their robust corrosion resistance, with advancements focusing on performance enhancement and surface modification techniques [18][19].

Advanced ceramic materials like zirconia and tungsten carbide exhibit exceptional resistance to high-temperature corrosion and abrasive wear [20]. Thermal spraying techniques deposit dense and uniform coatings, enhancing corrosion resistance in harsh environments [21]. Enhancing Corrosion Resistance with Surface Modification: Innovative surface passivation and roughening techniques fortify inorganic coatings against corrosion by repelling corrosive agents and promoting stable oxide layer formation [22][23]. Hybrid coatings combining organic polymers with inorganic materials offer superior mechanical strength and resistance to environmental stressors like corrosion [24]. These coatings find applications in automotive and maritime industries [25].

Applications of corrosion protection coating

Corrosion protection coatings are essential across industries like oil and gas, automotive, and renewable energy, with successful applications demonstrated in case studies. Emerging sectors like renewable energy and aerospace present unique challenges, demanding coatings with advanced functionalities to withstand extreme conditions. Research focuses on developing innovative coatings using new materials, nanostructured coatings, and advanced deposition techniques to enhance performance and sustainability.

FUTURE SCOPE

The evolution of corrosion protection coatings emphasizes sustainability and efficiency, driven by advanced materials and eco-friendly technologies. Research focuses on nanomaterials, self-healing mechanisms, and eco-friendly formulations to enhance corrosion resistance. Multifunctional coatings aim to integrate corrosion protection with self-cleaning or anti-fouling properties. Challenges include scaling up lab research, ensuring sustainability, and promoting collaboration among stakeholders. Future directions prioritize durability, sustainability, and the development of organic corrosion inhibitors derived from renewable resources.

CONCLUSION

This review covers corrosion protection coatings comprehensively, addressing principles, innovations, applications, and future trends. It stresses the economic and environmental importance of coatings in preventing losses and ecological harm. Coatings act as barriers against corrosion, with advancements in organic, inorganic, and ceramic coatings. Notable progress includes novel formulations, self-healing abilities, and nanotechnology integration, especially in organic coatings. Inorganic and ceramic coatings focus on high-temperature resilience and surface modifications. Hybrid coatings combine organic and inorganic elements for enhanced protection. Case studies highlight coating effectiveness in industries like oil and gas, automotive, and aerospace. Future directions include advanced materials like nanomaterials and eco-friendly coatings with self-cleaning properties. Collaboration and innovation are key to advancing corrosion protection coatings sustainably.

REFERENCES

1. J.R. Davis, The effects and economic impact of corrosion, in Corrosion: Understanding the basics, Netherlands: ASM International, 2000, pp. 62–66.
2. A.H.A. Nasser, P.D. Ndalila, E.A. Mawugbe, M.E. Kouame, M.A. Paterne, Y. Li, Mitigation of Risks Associated with Gas Pipeline Failure by Using Quantitative Risk Management Approach: A Descriptive Study on Gas Industry, J. Mar. Sci. Eng., 2021, 9, no. 10, 1098.
3. L.M. Muresan, Nanocomposite Coatings for Anti-Corrosion Properties of Metallic Substrates, Materials, 2023, 16, no. 14, 5092.
4. F.N. Jones, M.E. Nichols and S.P. Pappas, Organic coatings: science and technology, 2017, John Wiley & Sons, 2017.
5. P.S. Sidky and M.G. Hocking, Review of inorganic coatings and coating processes for reducing wear and corrosion, Br. Corros. J., 1999, 34, no. 3, 171–183.
6. F. Presuel-Moreno, M.A. Jakab, N. Tailleart, M. Goldman and J.R. Scully, Corrosion-resistant metallic coatings, Mater. Today, 2008, 11, no. 10, 14–23.
7. W. Giurlani, E. Berretti, M. Innocenti and A. Lavacchi, Measuring the thickness of metal coatings: A review of the methods, Coatings, 2020, 10, no. 12, 1211.
8. M.A. Malik, M.A. Hashim, F. Nabi, Sh.A. Al-Thabaiti and Z. Khan, Anti-corrosion ability of surfactants: A review, Int. J. Electrochem. Sci., 2011, 6, no. 6, 1927–1948.
9. J.B. Wachtman and A.H. Richard, Ceramic films and coatings, 1993, Noyes Publications: Park Ridge, NJ.
10. A. Stankiewicz, I. Szczygieł and B. Szczygieł, Self-healing coatings in anti-corrosion applications, J. Mater. Sci., 2013, 48, 8041–8051.
11. A.R. Heiba, F. Taher, R.M.A. Shahba and N.A.A. Ghany, Corrosion mitigation of carbon steel in acidic

and salty solutions using electrophoretically deposited graphene coatings, J. Coat. Technol. Res., 2020, 18, 501–510.

12. A.V. Radhamani, H.C. Lau and S. Ramakrishna, Nanocomposite coatings on steel for enhancing the corrosion resistance: A review, J. Compos. Mater., 2020, 54, no. 5, 681–701.

13. Y. Chang, X. Yan and Z. Wu, Application and prospect of self-healing microcapsules in surface coating of wood, Colloid Interface Sci. Commun., 2023, 56, 100736.

14. U. Eduok, E. Ohaeri and J. Szpunar, Self-healing composite coatings with protective and anticorrosion potentials: classification by healing mechanism, Self-Healing Compos. Mater., 2019, Woodhead Publishing, pp. 123–162.

15. C. Liu, H. Wu, Y. Qiang, H. Zhao and L. Wang, Design of smart protective coatings with autonomous self-healing and early corrosion reporting properties, Corros. Sci., 2021, 184, 109355.

16. M.H. Nazari, Y. Zhang, A. Mahmoodi, G. Xu, J. Yu, J. Wu and X. Shi, Nanocomposite organic coatings for corrosion protection of metals: A review of recent advances, Prog. Org. Coat., 2022, 162, 106573.

17. A.O. Ijaola, P.K. Farayibi and E. Asmatulu, Superhydrophobic coatings for steel pipeline protection in oil and gas industries: A comprehensive review, J. Nat. Gas Sci. Eng., 2020, 83, 103544.

18. E. Bakan, D.E. Mack, G. Mauer, R. Vaßen, J. Lamon and N.P. Padture, High-temperature materials for power generation in gas turbines, Advanced ceramics for energy conversion and storage, Ed. O. Guillon, 202, pp. 3–62.

19. A.A. Al-Amiery and W.K. Al-Azzawi, Organic Synthesized Inhibitors for Corrosion Protection of Carbon Steel: A Comprehensive Review, J. Bio Tribo Corros., 2023, 9, no. 4, 74.

20. U. Eduok, J. Szpunar and E. Ebenso, Synthesis and characterization of anticorrosion zirconia/acrylic nanocomposite resin coatings for steel, Prog. Org. Coat., 2019, 137, 105337.

21. Y.X. Wang and S. Zhang, Toward hard yet tough ceramic coatings, Surf. Coat. Technol., 2014, 258, 1–16.

22. U.A. Samad, M.A. Alam, H.S. Abdo, A. Anis and S.M. Al-Zahrani, Synergistic Effect of Nanoparticles: Enhanced Mechanical and Corrosion Protection Properties of Epoxy Coatings Incorporated with SiO2 and ZrO2, Polymers, 2023, 15, no. 14, 3100.

23. A.G. Karem, Synthesis, characterisation and anti-corrosion behaviour of NiO-CNTs-SnO2 nanocomposites coatings on AISI 1020 steel, PhD Diss., 2021.

24. C. Qi, C.E. Weinell, K. Dam-Johansen and H. Wu, Assessment of Anticorrosion Performance of Zinc-Rich Epoxy Coatings Added with Zinc Fibers for Corrosion Protection of Steel, ACS Omega, 2023, 8, no. 2, 1912–1922.

25. A. Wang, K. De Silva, M. Jones, P. Robinson, G. Larribe and W. Gao, Anticorrosive coating systems for marine propellers, Prog. Org. Coat., 2023, 183, 107768.

Review of Concepts in Graph Theory and Its Applications

Gouri Gurunath Dandekar
Assistant Professor
Department of Applied Science & Huminities
VPM's MPCOE
Velneshwar, Maharashtra

Swanand Joshi
Department of Mechanical Engineering
VPM's Maharshi Parshuram College of Engineering
Velneshwar, Maharashtra

ABSTRACT

Graph theory has applications in a wide range of fields. Graph theory involves various types of graphs, theorems related to them, various algorithms. Graph theory has applications is field like Computer Science, Engineering, Biology, Social Network, Operation Research etc. This research paper discusses about various concepts in graph theory and fields or real-life situations where we can apply them.

KEYWORDS *: Graph, Eulerian graph, Hamiltonian graph, Graph coloring, Flow theory.*

INTRODUCTION

Graph Theory is branch of Mathematics which deals with the study of graphs, which are mathematical structures used to model pairwise relations between objects. These objects are represented as vertices, and the relations between them are represented as edges. The diverse nature of graphs, characterized by their structure, properties, and applications, has led to the development of various types of graphs, algorithms, and theorems. These different types of graphs, algorithms, and theorems are tailored to specific applications based on their unique characteristics. From directed and undirected graphs to weighted and unweighted graphs, each type serves distinct purposes in modeling real-world systems. This research paper discusses four distinct aspects of graphs and their applications, showcasing the versatility and significance of graph theory across different domains.

Eulerian Graph

A Eulerian graph is a graph where every vertex has an even degree. The study of Eulerian graphs played a pivotal role in the development of graph theory as a mathematical discipline. Eulerian graphs are named after the Swiss mathematician Leonhard Euler, who in 1736, while solving the famous Seven Bridges of Königsberg problem, introduced the concept of Eulerian paths and circuits.

The Seven Bridges problem involved determining if a path exists that cross each of the seven bridges in Königsberg exactly once and returns to the starting point. Euler approached this problem by abstracting it into a mathematical structure now known as a graph. In Euler's formulation, vertices represented landmasses, and edges represented bridges. [Fig.1]

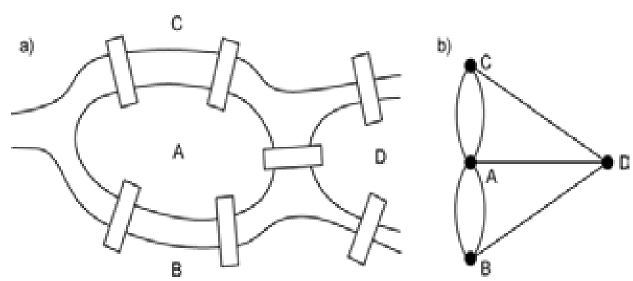

Fig. 1

APPLICATIONS

Transportation Networks

Eulerian graphs are used in analyzing traversal paths within networks because of their unique properties. By representing a network as a Eulerian graph, one can determine if there exists a Eulerian circuit or trail that covers all edges exactly once, which is crucial for efficient traversal.[4]

In a transportation network with multiple delivery stops, Eulerian graphs can be used to analyze traversal paths and find optimal routes for delivery vehicles. The Eulerian circuit in such a graph would represent an efficient route that covers all stops exactly once, minimizing travel time and fuel consumption.

Circuit Design

In electrical engineering, Eulerian graphs are used to design circuits with specific connectivity requirements. The concept of Eulerian circuits helps ensure that all components in a circuit are connected efficiently.[5]

Flow Theory

Flow theory deals with the study of flows within networks represented as graphs. It involves modeling the movement or transfer of quantities, such as fluids, data packets, or resources, through interconnected nodes and edges in a graph.

A graph is used to represent the network, where nodes (vertices) represent entities like sources, sinks, or intermediate points, and edges represent connections or paths between nodes. Each edge in the graph has a capacity, which signifies the maximum amount of flow that can pass through it.

APPLICATIONS

Supply Chain Management

Supply Chain Management applies graph theory with flow theory concepts to optimize the flow of goods, resources, and information through the supply chain network. This approach helps reduce costs, improve efficiency, and enhance decision-making in logistics, inventory management, and distribution planning. Algorithms like minimum cost flow and network flow optimization are used to model and analyze supply chain networks, ensuring smooth operations and timely deliveries.

CONCLUSION

This research paper delves into fundamental graph theory concepts and their practical applications, fostering interest and enhancing understanding. Eulerian graphs optimize traversal paths, Hamiltonian graphs solve optimization problems like the Traveling Salesman Problem, and graph coloring aids in efficient organization. Additionally, flow theory optimizes flow in networks, improving decision-making and reducing costs in transportation and supply chain management. Studying concepts in this manner may generate interest in the subject and clarify concepts in a better way.

REFERENCES

1. A. Prathik, K. Uma, J. Anuradha, An Overview of application of Graph theory, International Journal of Chem Tech Research
2. Narasingh Deo, “Graph theory with applications to engineering and computer science”, Prentice Hall of India, 1990
3. Biggs, N. L.; Lloyd, E. K.; Wilson, R. J. “Graph Theory 1736-1936.
4. https://en.wikipedia.org/wiki/Graph_theory#cite_ref-1
5. Dankan V. Gowda1 , K.S. Shashidhara, M. Ramesha, S.B. Sridhara, and S.B. Manoj Kumar, RECENT ADVANCES IN GRAPH THEORY AND ITS APPLICATIONS, Advances in Mathematics: Scientific Journal 10 (2021).

A Study of Fundamental Properties of General Huff Curves Defined Over the Special Ring

Ankit Chaudhary*
✉ aakashdhama2016@gmail.com

Manoj Kumar
✉ sdmkg1@gmail.com

Department of Mathematics and Statistics
Gurukula Kangri (Deemed to be University)
Haridwar, Uttarakhand

ABSTRACT

Elliptic curves defined over rings extend the traditional study of elliptic curves beyond fields. The foundational work on elliptic curves are initially developed over fields but the extension to rings offers new perspectives and applications in algebraic geometry, number theory, and cryptography. We investigate the structure of an elliptic curve defined over a ring, particularly in the context of the huff form and definitions based on rings. The present work involves the analysis of certain fundamental properties of the special ring. In this paper we generalized the general huff curves over special ring and after defining the huff form over the ring, we study the essential properties such as an addition and isogeny formula etc. So, the study of elliptic curves over the ring structure will provide a broader range of isogeny-based cryptography. We have provided the brief analysis of algebraic complexity of these formulas and the future work are also discussed.

KEYWORDS : *Elliptic curves. Supersingular elliptic curves. Elliptic curve cryptography. Isogenies. Polynomial ring. Post-quantum cryptography.*

INTRODUCTION

The study of an elliptic curves has a wide history in algebraic geometry and number theory dating back to the around 19th century. Major progress in the study of elliptic curves over finite fields occurred, ultimately resulting in the independent proposals of the elliptic curve cryptosystem [17, 21]. The traditional representation of elliptic curves often uses the short weierstrass form, but different forms have been explored for faster scalar multiplications. In the literature, it has been noted by researchers that for faster scalar multiplications, there have been different forms of elliptic curves explored. Since, the foundational work on ECs is initially developed over finite fields, the extension to rings offers new perspectives and applications in algebraic geometry, number theory, and cryptography. ECs defined over the finite fields work as a foundation in isogeny-based cryptography. In literature, it has been noted by researchers [6,14] that that ECs in terms of isogenies can also become good candidates to provide security for near term quantum cryptosystems. So, the study of elliptic curves over the ring structure can provide a broader range of isogeny-based cryptography. One of the elliptic curves that has gained the attention of researchers is the Huff form [15] developed an EC model introduced by Huff [13] to study a diophantine problem and later Wu and Feng [30] introduced the General Huff curves. Chillali [1] presented work on ring F_q $[q]$, $e_n = 0$. Kumar et al. [19] proposed cryptographic schemes based on ECs over ring. Recently Grini et al. [12] also presented twisted hessian curves cryptography over the local ring. In this paper we study the General Huff Curves over ring F_q $[q]$, $e^2 = 0$ and fundamental properties.

PRELIMINARIES

In this section we shall discuss the fundamental concepts related to special rings and general huff curves.

Ring : R_n Let be an odd prime number and represent an integer such that n ≥ 2. Consider the quotient ring $R_n = \frac{F_q[X]}{(X^n)}$ where is the finite field of characteristic and elements. Then the ring R_n may be identified to the ring

$F_q[e]$ where e^n [1].

In other word,

$$R_n = \left\{ \sum_{i=0}^{n-1} x_i e^i \left| (x_i)_{0 \le i \le n-1} \in F_q^n \right. \right\}$$

then ring R_n can be defined as

$$R_2 = x_0 e^0 + x_1 e^1$$
$$R_2 = x_0 + x_1 e$$

Huff elliptic curve: Huff models for ECs were first introduced by Joye et al. [15]. The generalised form of Huff curves is proposed by [30]. The equations for General Huff curves are as follows:

$$G_{a,b} : x\left(ay^2 - 1\right) = y\left(bx^2 - 1\right)$$

Addition formula: On the General Huff curve, the addition of two points [30] where and can be defined as:

$$x_r = \frac{\left(x_p + x_q\right)\left(ay_p y_q + 1\right)}{\left(bx_p x_q + 1\right)\left(ay_p y_q - 1\right)} \quad (1)$$

$$y_r = \frac{\left(y_p + y_q\right)\left(bx_p x_q + 1\right)}{\left(bx_p x_q - 1\right)\left(ay_p y_q + 1\right)} \quad (2)$$

PROPOSED WORK

In this section, first we study the structure of the general huff curves over a ring. Then we find out the addition formula for this structure because combining two points on an EC, an essential procedure in cryptographic contexts, Furthermore, we derive the doubling formula after using the compression function of degree 2.

Theorem 1 Let p be an odd prime number and n represent an integer such that n ≥ 2 . Then the general huff curve over ring R_2 denoted by $G_{G_{a,b}}$ is defined as follows:

$$G_{G_{a,b}} : x_0\left(a_0 {y_0}^2 - 1\right) = y_0\left(b_0 {x_0}^2 - 1\right) + e\left[D + Ax_1 + By_1\right]$$

where

$$D = y_0 b_1 x_0^2 - x_1 a_0 y_0^2, \quad A = y_0 2b_0 x_0 - x_0 a_1 y_0^2 + 1,$$
$$B = b_0 x_0^2 - 1 - x_0 2a_0 y_0.$$

Proof We know that the general huff curve defined over field

$$G_{a,b} : x\left(ay^2 - 1\right) = y\left(bx^2 - 1\right)$$

First, we take the left part of the above equation

$$x\left(ay^2 - 1\right) = \left(x_0 + x_1 e\right)\left[\left(a_0 + a_1 e\right)\left(y_0 + y_1 e\right)^2 - 1\right]$$
$$= \left(x_0 + x_1 e\right)\left[\left(a_0 + a_1 e\right)\left(y_0^2 + y_1^2 e^2 + 2y_0 y_1 e\right) - 1\right]$$
$$= x_0 a_0 y_0^2 + x_0 2a_0 y_0 y_1 e + x_0 a_1 e y_0^2 + x_1 e a_0 y_0^2 - x_0 - x_1 e$$
$$x\left(ay^2 - 1\right) = x_0\left(a_0 y_0^2 - 1\right) + e\left(x_0 2a_0 y_0 y_1 + x_0 a_1 y_0^2 + x_1 a_0 y_0^2 - x_1\right) \quad (3)$$

Similarly, we can compute the right side

$$y\left(bx^2 - 1\right) = y_0\left(b_0 x_0^2 - 1\right) + e\left(y_0 2b_0 x_0 x_1 + y_0 b_1 x_0^2 + y_1 b_0 x_0^2 - y_1\right) \quad (4)$$

Now from equations (3) and (4) we get,

$$x_0\left(a_0 {y_0}^2 - 1\right) = y_0\left(b_0 {x_0}^2 - 1\right) + e\left[D + Ax_1 + By_1\right]$$

where

$$D = y_0 b_1 x_0^2 - x_0 a_1 y_0^2, \quad A = y_0 2b_0 x_0 - a_0 y_0^2 + 1,$$
$$B = b_0 x_0^2 - 1 - x_0 2a_0 y_0.$$

Addition formula for $G_{G_{a,b}}$

The combining of two points on an EC is a fundamental process in elliptic curve cryptography, serving as a vital operation in numerous cryptographic protocols. Here we derive the addition formula for the general Huff curve defined over ring.

Theorem 2 Let P, q, a and b points on general Huff curve defined over ring R_2 then addition $P + Q = R$ (x_r, y_r) of two points *P, Q* defined as below:

$$x_r = \frac{\left[x_{0p} + x_{0q} + \left(x_{1p} + x_{1q}\right)e\right]\left(a_0 y_{0p} y_{0q} + 1\right) + P^* e\left(x_{0p} + x_{0q}\right)}{\left(b_0 x_{0p} x_{0q} + 1\right)\left(a_0 y_{0p} y_{0q} - 1\right) + P^* e\left(b_0 x_{0p} x_{0q} + 1\right) + Q^* e\left(a_0 y_{0p} y_{0q} - 1\right)}$$

$$y_r = \frac{\left[y_{0p} + y_{0q} + \left(y_{1p} + y_{1q}\right)e\right]\left(b_0 x_{0p} x_{0q} + 1\right) + Q^* e\left(y_{0p} + y_{0q}\right)}{\left(b_0 x_{0p} x_{0q} - 1\right)\left(a_0 y_{0p} y_{0q} + 1\right) + P^* e\left(b_0 x_{0p} x_{0q} - 1\right) + Q^* e\left(a_0 y_{0p} y_{0q} + 1\right)}$$

where $P^* = a_0 y_{0p} y_{1q} + a_0 y_{1p} y_{0q} + a_1 y_{0p} y_{0q}$

$Q^* = b_0 x_{0p} x_{1q} + b_0 x_{1p} x_{0q} + b_1 x_{0p} x_{0q}$

Proof $P = \left(x_{0p} + x_{1p}e,\ y_{0p} + y_{1p}\right)$ and $Q = \left(x_{0q} + x_{1q}e,\ y_{0q} + y_{1q}\right)$ be two point of general huff curve defined over ring R_2. Put the values of P and Q in the equation (1) and (2), we get

$$x_r = \frac{\left(x_{0p}+x_{1p}e+x_{0q}+x_{1q}e\right)\left[\left(a_0+a_1e\right)\left(y_{0p}+y_{1p}e\right)\left(y_{0q}+y_{1q}e\right)-1\right]}{\left[\left(b_0+b_1e\right)\left(x_{0p}+x_{1p}e\right)\left(x_{0q}+x_{1q}e\right)+1\right]\left[\left(a_0+a_1e\right)\left(y_{0p}+y_{1p}e\right)\left(y_{0q}+y_{1q}e\right)-1\right]} \quad (5)$$

$$y_r = \frac{\left(y_{0p}+y_{1p}e+y_{0q}+y_{1q}e\right)\left[\left(b_0+b_1e\right)\left(x_{0p}+x_{1p}e\right)\left(x_{0q}+x_{1q}e\right)+1\right]}{\left[\left(b_0+b_1e\right)\left(x_{0p}+x_{1p}e\right)\left(x_{0q}+x_{1q}e\right)-1\right]\left[\left(a_0+a_1e\right)\left(y_{0p}+y_{1p}e\right)\left(y_{0q}+y_{1q}e\right)+1\right]} \quad (6)$$

First, we solve

$$\begin{aligned}\left(a_0+a_1e\right)\left(y_{0p}+y_{1p}e\right)\left(y_{0q}+y_{1q}e\right) &= \left(a_0+a_1e\right)\left(y_{0p}.y_{0q}+y_{0p}.y_{1q}e+y_{1p}.y_{0q}e\right)\\ &= a_0.y_{1p}.y_{0q}+e\left(a_0.y_{0p}.y_{1q}+a_0.y_{1p}.y_{0q}+a_1.y_{0p}.y_{0q}\right)\end{aligned}$$

Let $P^* = a_0 y_{0p}.y_{1q} + a_0 y_{1p}.y_{0q} + a_1 y_{0p}.y_{0q}$

Then $\left(a_0+a_1e\right)\left(y_{0p}+y_{1p}e\right)\left(y_{0q}+y_{1q}e\right) = a_0 y_{0p}.y_{0q} + P^*e$,

$\left(b_0+b_1e\right)\left(x_{0p}+x_{1p}e\right)\left(x_{0q}+x_{1q}e\right) = b_0 x_{0p}.x_{0q} + Q^*e$,

where $Q^* = b_0 x_{0p}.x_{1q} + b_0 x_{1p}.x_{0q} + b_1 x_{0p}.x_{0q}$.

Now put these values in equation (5), we get

$$x_r = \frac{\left(x_{0p}+x_{1p}e+x_{0q}+x_{1q}e\right)\left(a_0.y_{0p}.y_{0q}+1+P^*e\right)}{\left(b_0x_{0p}.x_{0q}+1+Q^*e\right)\left(a_0.y_{0p}.y_{0q}-1+P^*e\right)}$$

$$x_r = \frac{\left[x_{0p}+x_{0q}+\left(x_{1p}+x_{1q}\right)e\right]\left(a_0.y_{0p}.y_{0q}+1\right)+P^*e\left(x_{0p}+x_{0q}\right)}{\left(b_0x_{0p}.x_{0q}+1\right)\left(a_0.y_{0p}.y_{0q}-1\right)+P^*e\left(b_0x_{0p}.x_{0q}+1\right)+Q^*e\left(a_0.y_{0p}.y_{0q}-1\right)}$$

Similarly, the second coordinate

$$y_r = \frac{\left[y_{0p}+y_{0q}+\left(y_{1p}+y_{1q}\right)e\right]\left(b_0x_{0p}.x_{0q}+1\right)+Q^*e\left(y_{0p}+y_{0q}\right)}{\left(b_0x_{0p}.x_{0q}-1\right)\left(a_0.y_{0p}.y_{0q}+1\right)+P^*e\left(b_0x_{0p}.x_{0q}-1\right)+Q^*e\left(a_0.y_{0p}.y_{0q}+1\right)}$$

Construction of Isogeny over structure of General Huff curves defined over Ring R_2

Isogeny is a special type of morphism that occurs between elliptic curves, which are algebraic geometric structures applied in the field of cryptography. So, in this section, we derive the construction an isogeny for General Huff curves over a ring structure.

Theorem 4 Let G be the kernel of an isogeny and the set of points $G=\{(0,0),(\pm\alpha_s,\pm\beta_s):i=1,2,....s\}$. Then ϕ is a l– isogeny with kernel G from $G_{G_{a,b}}$ to the curve $G_{G_{\hat{a},\hat{b}}}$, where $\hat{a}=a^l B^4$ and $\hat{b}=b^l A^4$, with $A=\prod_{i=1}^{s}\alpha_i$ and $B=\prod_{i=1}^{s}\beta_i$, is given by

$$\phi\left(x_0+x_1e,\ y_0+y_1e\right)=$$

$$\left(\frac{x_0+x_1e}{A^2}\prod_{i=1}^{s}\frac{\alpha_{i0}^2-x_0^2+e\left(M-N\right)}{1-b_0^2\alpha_0^2x_0^2-e\left(P+Q+R\right)},\ \frac{y_0+y_1e}{B^2}\prod_{i=1}^{s}\frac{\beta_{i0}^2-y_0^2+e\left(M'-N'\right)}{1-a_0^2\beta_0^2y_0^2-e\left(P'+Q'+R'\right)}\right)$$

where

$M=2\alpha_{i0}\alpha_{i1}$, $N=2x_0x_1$

$P=b_0^2 2\alpha_{i0}\alpha_{i1}x_0^2$, $Q=2b_0b_1\alpha_{i0}^2x_0^2$, $R=b_0^2\alpha_{i0}^2 2x_0x_1$

$M'=2\beta_{i0}\beta_{i1}$, $N'=2y_0y_1$

$P'=a_0^2 2\beta_{i0}\beta_{i1}y_0^2$, $Q'=2a_0a_1\beta_{i0}^2y_0^2$, $R'=a_0^2\beta_{i0}^2 2y_0y_1$

Proof. Put the values of x, y, α_i, β_i, a and b are in the following formula [22]

$$\phi(x,y)=\left(\frac{x}{A^2}\prod_{i=1}^{s}\frac{\alpha_i^2-x^2}{1-b^2\alpha_i^2x^2},\ \frac{y}{B^2}\prod_{i=1}^{s}\frac{\beta_i^2-y^2}{1-a^2\beta_i^2y^2}\right)$$

Then

$$\phi\left(x_0+x_1e,\ y_0+y_1e\right)=$$

$$\left(\frac{x_0+x_1e}{A^2}\prod_{i=1}^{s}\frac{\left(\alpha_{i0}+\alpha_{i1}e\right)^2-\left(x_0+x_1e\right)^2}{1-b^2\left(\alpha_{i0}+\alpha_{i1}e\right)_i^2\left(x_0+x_1e\right)^2},\ \frac{y_0+y_1e}{B^2}\prod_{i=1}^{s}\frac{\left(\beta_{i0}+\beta_{i1}e\right)^2-\left(y_0+y_1e\right)^2}{1-a^2\left(\beta_{i0}+\beta_{i1}e\right)^2\left(y_0+y_1e\right)^2}\right) \quad (8)$$

First, we solve these values,

$$\left(\alpha_{i0}+\alpha_{i1}e\right)^2-\left(x_0+x_1e\right)^2 = \alpha_{i0}^2+\alpha_{i1}^2e^2+2\alpha_{i0}\alpha_{i1}e-x_0^2-x_1^2e^2-2x_0x_1e$$

Let

$M=2\alpha_{i0}\alpha_{i1}$, $N=2x_0x_1$

$$\left(\alpha_{i0}+\alpha_{i1}e\right)^2-\left(x_0+x_1e\right)^2 = \alpha_{i0}^2-x_0^2+e\left(M-N\right)$$

Next, we solve the denominator part of first coordinate

$$\begin{aligned}&1-\left(b_0+b_1e\right)^2\left(\alpha_{i0}+\alpha_{i1}e\right)^2\left(x_0+x_1e\right)^2\\ &=1-\left[\left(b_0^2+b_1^2e^2+2b_0b_1e\right)\left(\alpha_{i0}^2+\alpha_{i1}^2e^2+2\alpha_{i0}\alpha_{i1}e\right)\left(x_0^2+x_1^2e^2+2x_0x_1e\right)\right]\\ &=1-\left[\left(b_0^2+2b_0b_1e\right)\left(\alpha_{i0}^2+2\alpha_{i0}\alpha_{i1}e\right)\left(x_0^2+2x_0x_1e\right)\right]\\ &=1-\left[b_0^2\alpha_{i0}^2x_0^2+e\left(b_0^2 2\alpha_{i0}\alpha_{i1}x_0^2+2b_0b_1\alpha_{i0}^2x_0^2+b_0^2\alpha_{i0}^2 2x_0x_1\right)\right]\end{aligned}$$

Let $P=b_0^2 2\alpha_{i0}\alpha_{i1}x_0^2$, $Q=2b_0b_1\alpha_{i0}^2x_0^2$, $R=b_0^2\alpha_{i0}^2 2x_0x_1$

Then, $1-\left(b_0+b_1e\right)^2\left(\alpha_{i0}+\alpha_{i1}e\right)^2\left(x_0+x_1e\right)^2=1-b_0^2\alpha_{i0}^2x_0^2-e\left(P+Q+R\right)$

Similarly, we can compute the numerator and denominator parts of the second coordinates, respectively

$$(\beta_{i0}+\beta_{i1}e)^2-(y_0+y_1e)^2=\beta_{i0}^2-y_0^2+e(M'-N'),$$

where $M'=2\beta_{i0}\beta_{i1}$, $N'=2y_0y_1$

and $1-a^2(\beta_{i0}+\beta_{i1}e)_i^2(y_0+y_1e)^2=1-a_0^2\beta_{i0}^2y_0^2-e(P'+Q'+R')$

where $P'=a_0^2 2\beta_{i0}\beta_{i1}y_0^2$, $Q'=2a_0a_1\beta_{i0}^2y_0^2$, $R'=a_0^2\beta_{i0}^2 2y_0y_1$

Now, put the values of first and second coordinates in equation (8), we get

$$\phi(x_0+x_1e,\ y_0+y_1e)=$$
$$\left(\frac{x_0+x_1e}{A^2}\prod_{i=1}^{s}\frac{\alpha_{i0}^2-x_0^2+e(M-N)}{1-b_0^2\alpha_0^2x_0^2-e(P+Q+R)},\ \frac{y_0+y_1e}{B^2}\prod_{i=1}^{s}\frac{\beta_{i0}^2-y_0^2+e(M'-N')}{1-a_0^2\beta_0^2y_0^2-e(P'+Q'+R')}\right)$$

COMPUTATION

In this section we compute total operations counts of addition, doubling and isogeny formulae for General Huff curves over ring. Let C, M and S denote by constant, multiplication and squaring in ring respectively. So, total operation counts for addition, doubling after using compression function and isogeny formulas are given in following table:

Table 1. Total operations counts for different formulae

S.No.	Formulas	Operation Counts
1.	Addition	20M + 13A + 6C + 2I
2.	Isogeny	(8s+4) M + (14s+2) A + 2S + 12sC + 2I

CONCLUSION AND FUTURE WORKS

In this work, we study General Huff curves defined over a special ring as well as associated properties such as addition and isogeny formula. For isogeny, we start with Moody and Shumow's work as a basis formula and derive an isogeny formula for this curve defined over a ring. Finally, we compute the total operation counts for derived formulas. This paper opens numerous possibilities for future research. We can improve the addition and isogeny formulas by using projective coordinates and projective curve coefficients. One notable area is the need for additional research into the computational efficiency of the Huff form, especially when compared to alternative representations of elliptic curves models.

REFERENCES

1. Abdelhakim, C.: Elliptic Curve of the Ring Fq [ϵ]. In International Mathematical Forum 6(31), 1501-1505 (2011)

2. Charles, D.X., Lauter, K.E., Goren, E.Z.: Cryptographic hash functions from expander graphs, J o u r n a l of Cryptology. 22(1), 93-113 (2009). https://doi.org/10.1007/s00145-007-9002-x

3. Couveignes, J.M.: Hard homogeneous spaces. Cryptology ePrint Archive (2006)

4. Grini, A., Chillali, A., Fadil, L.E., Mouanis, H.: Twisted Hessian curves over the ring F q [∊],∊ 2= 0. International Journal of Computer Aided Engineering and Technology. 18(1-3), 181-189 (2023). https://doi.org/10.1504/IJCAET.2023.127795

5. Huff, G.B.: Diophantine problems in geometry and elliptic ternary forms. Duke Mathematical, Journal. 15(2), 443-445 (1948). https://doi.org/10.1215/S0012-7094-48-01543-9

[6] Jao D and Feo L. D.: Towards quantum-resistant cryptosystems from supersingular elliptic curve isogenies, In International Workshop on Post-Quantum Cryptography, Springer, Berlin, Heidelberg, 19-34 (2011). https://doi.org/10.1007/978-3-642-25405-5_2

7. Joye, M., Tibouchi, M., Vergnaud, D., Huff's model for elliptic curves. In Algorithmic Number Theory: 9th International Symposium, ANTS-IX, Nancy, France, July 19-23, 2010.Proceedings 9 (pp. 234-250). Springer Berlin Heidelberg (2010)

8. Kim, S.: Complete analysis of implementing isogeny-based cryptography using huff form of elliptic curves. IEEE Access, 9. 154500-154512 (2021). https://doi.org//10.1109/ACCESS.2021.3128515

9. Koblitz, N.: Elliptic curve cryptosystems. Mathematics of computation. 48(177), 203-209 (1987)

10. Kumar, M., Gupta, P.: Cryptographic schemes based on elliptic curves over the ring. Applied Mathematics. 7(3), 304-312 (2016).

11. Miller, V.S., August. Use of elliptic curves in cryptography. In Conference on the theory and application of cryptographic techniques (417-426). Berlin, Heidelberg: Springer Berlin Heidelberg (1985)

12. Moody, D., Shumow, D.: Analogues of Vélu's formulas for isogenies on alternate models of elliptic curves. Mathematics of Computation. 85(300), 1929-1951 (2016).

13. Rostovtsev, A. and Stolbunov, A., 2006. Public-key cryptosystem based on Isogenies. Cryptology ePrint Archive.

14. Washington, L.C.: Elliptic Curves: Number Theory and Cryptography, 2nd edn. CRC Press, Boca Raton (2008)

15. Wu, H., Feng, R.: Elliptic curves in Huff's model. Wuhan University Journal of Natural Sciences. 17(6), 473-480 (2012). https://doi.org/10.1007/s11859-012-0873-9.

Photo Electrochemical Performance of Spray Deposited CIGS-ZnO Composite Thin Film

Amit. S. Joshi
Department of applied Science and Humanities
VPM's Maharishi Parshuram College of Engineering
Velneshwar, Maharashtra
✉ phyamit1995@gmail.com

Padmanabh S. Sarpotdar
G. B. Tatha Tatyasaheb Khare Commerce
Parvatibai Gurupad Dhere Arts and
sShri. Mahesh Janardan Bhosale Science College,
Guhagar, Maharashtra
✉ padphy@gmail.com

ABSTRACT

The ZnO and CIGS-ZnO composite thin films were deposited by simple and cost-effective spray pyrolysis technique by using aqueous solution of 0.5 M Zinc acetate and mixture of CIGS and Zinc acetate solution onto the glass and FTO substrates. The CIGS concentrations were varied such as 0.005, 0.0075, 0.01, 0.0125 g/40ml of solution for the depositions of CIGS-ZnO nanocomposites. XRD analysis confirms the formation of ZnO and CIGS-ZnO nanocomposite. The granular surface morphology is observed for ZnO while large grains of CIGS with tiny ZnO nanograins are observed for CIGS-ZnO nanocomposite. The optical studies shows that a UV absoption edge for ZnO while CIGS-ZnO thin films shows the good absorption in visible region. The PEC performance of ZnO and CIGS-ZnO film is observed. The efficiency of ZnO and CIGS- ZnO thin film is found to be 0.004% and 0.04%. The addition of CIGS increases the efficiency.

KEYWORDS *: Spray pyrolysis, ZnO, CIGS, PEC.*

INTRODUCTION

Zinc oxide thin films are widely used in solar cells from many years. In recent year the new material Copper Indium Gallium selenide (CIGS) becomes a promising material for the solar cell application. The lab Efficiency of CIGS solar cell goes beyond 21%. [1,2]. The solar radiation reaching earth surface has high intensity in visible region. CIGS and ZnO has absorption peak in visible and UV region of solar spectrum respectively. In this work we develop CIGS-ZnO composite thin films for reducing the band gap of ZnO, So that it can absorb radiation in both UV and Visible region. The synthesis of CIGS-ZnO thin films are done by Spray Pyrolysis Technique. The effect of CIGS concentration on absorption of radiation is investigated. The PEC performance of CIGS –ZnO composite thin film showing best absorption is compared with PEC performance of ZnO thin film.

EXPERIMENTAL DETAILS

Optimisation of Parameter for ZnO thin film deposition

The ZnO thin film is deposited by using aqueous solution of 0.05M Zinc Acetate [3,4]. The various parameters like substrate temperature, spray rate, substrate to nozzle distance are optimised for ZnO deposition. The optimised value of this parameter is given in table 1.

Deposition of CIGS-ZnO composite thin films

The CIGS – ZnO composite thin films are deposited by mixing CIGS nanoparticles in precursor solution of 0.05M Zinc Acetate. The concentration of CIGS is varied from 0.0050 g to 0.0125 g. The optimised parameter from table 1 is used at time of deposition. The nomenclature is done for deposited films as C1 C2, C3, and C4 for CIGS concentration of 0.0050, 0.0075, 0.0100 and 0.0125g respectively.

Table 1: Optimised parameter for thin film deposition

Parameter	Value
Deposition method	Spray pyrolysis
Precursor solution	0.05 [M] Zinc Acetate
Precursor Volume	40 [ml]
Substrate temperature	450 [degree celcius]
Substrate to nozzle distance	20 [cm]
Substrates	Glass And FTO
Spray rate	3 [ml/min]

Characterisation

The XRD and SEM are used for confirmation of formation of ZnO and CIGS-ZnO composite thin films. The contact angle measurement is used to check hydrophilic and hydrophobic nature of thin films. The UV - Visible spectroscopy is used for study of absorption spectrum and band gap calculation. The CIGS- ZnO composite thin film showing best absorption is used for comparison of efficiency in PEC performance with ZnO thin film.

RESULT AND DISCUSSION

XRD

The XRD analysis of deposited films confirms the deposition of the ZnO and CIGS –ZnO composite thin films. Fig 1 & 2 shows the XRD pattern for ZnO and CIGS – ZnO composite fims. The XRD patterns were oriented in (100), (002), (101), (102), (110), (103) and (112) planes.[5] The oriented XRD data are exactly matched with JCPDS (Card No. 36-1451) for ZnO and (Card No. 35-1102) for CIGS . The diffraction peaks positioned at 2θ=31.96°, 34.53°, 36.29°, 56.74°, 62.95°, and 68.32° for ZnO and 2θ=26.5° for CIGS.[6]

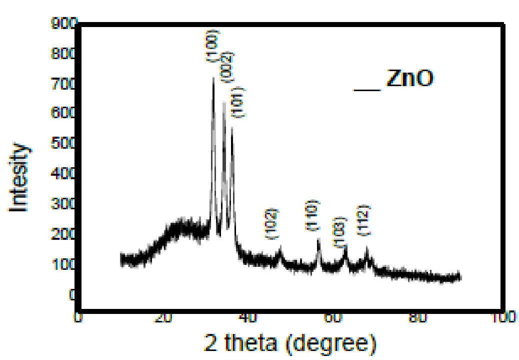

Fig 1 XRD pattern for ZnO

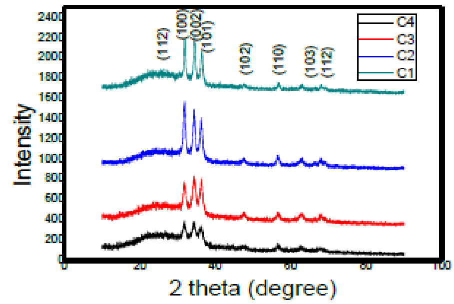

Fig 2 XRD pattern for CIGS - ZnO

3.2. SEM - The Fig 3. & 4 Shows SEM images for ZnO and CIGS-ZnO (C4) composite thin films, respectively. The uniform granular morphology is observed for both films. The CIGS nanoparticle are located in between the ZnO nanoparticles with large grain size. The average grain size 20-25 nm for ZnO and 70-75 nm is observed for CIGS-ZnO composite thin film.

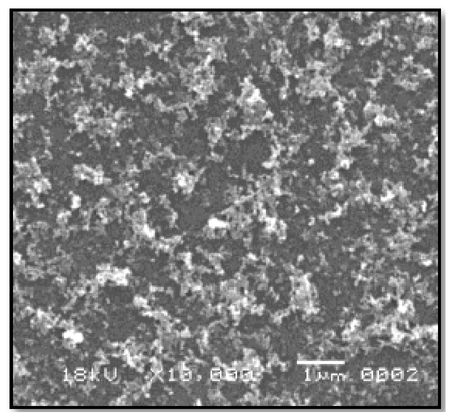

Fig 3 SEM image for ZnO thin film

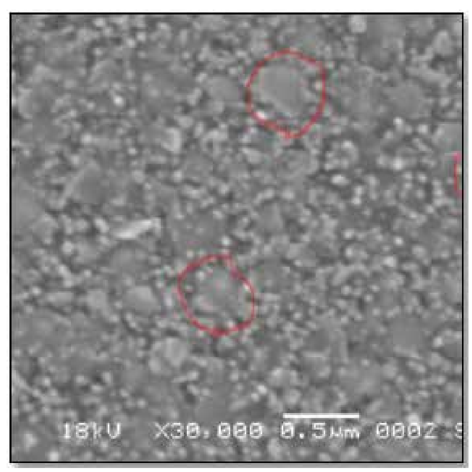

Fig 4 SEM image for CIGS- ZnO film

UV

Visible Spectroscopy - The UV-Vis spectroscopy is used to study the absorption spectrum of films and to calculate the band gap energy. It is observed that for CIGS-ZnO composite thin film C4 has maximum absorption in UV-Visible region than C1-C3 films. The fig 5 Shows comparison for absorption spectra of ZnO and C4 films. It indicates that CIGS- ZnO thin film C4 has better absorption than ZnO thin film. The band gap is calculated from Tauc plot. The band of 3.29 eV is observed for ZnO and for C4 film it is 3.14 eV.

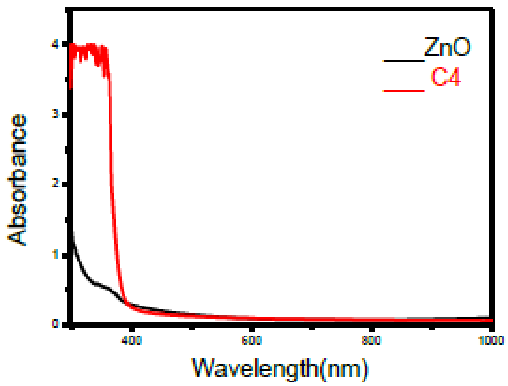

Fig 5 Absorption spectra for C4 anf ZnO thin film

Contact angle measurement

The contact angle is measured with respect to water. The contact angle observed for films C1, C2, C3, and C4 are 128.10, 107.60, 75.80, 50.90 respectively. It is observed that contact angle is decrease with increase in CIGS concentration, it indicates film possess hydrophobic to hydrophilic in nature.

PEC performance

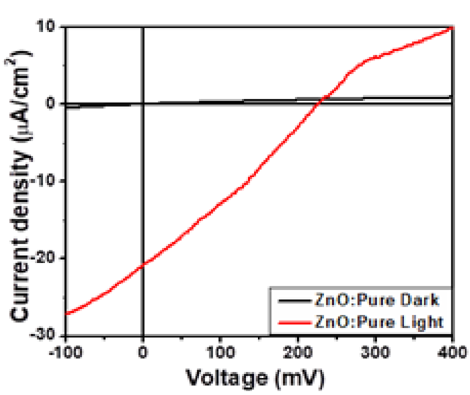

Fig 6 IV characteristics curve for ZnO thin film

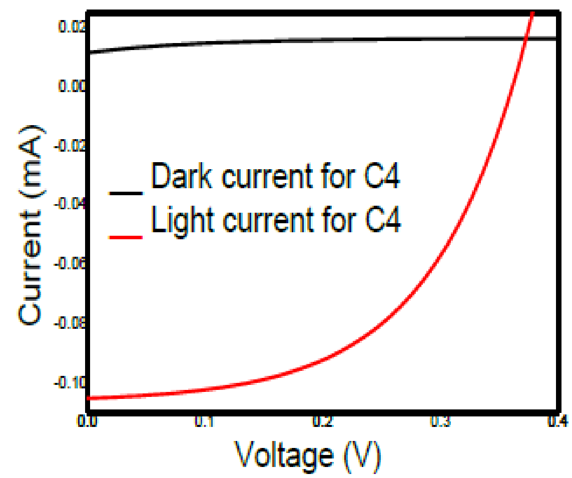

Fig 7 characteristics curve for C4 thin film

As C4 film best absorption spectrum in UV-Visible region. We choose C4 film for comparison of PEC performance with ZnO thin film.The fig 6&7 shows the I-V characteristics of ZnO and CIGS-ZnO composite film (C4). The PEC performance is checked against the graphite electrode and 0.5M Sodium sulphate is used as electrolyte. The input power is P_{in} = 30 mW/cm^2.

The efficiency and FF is calculated by formula [1]

$$Efficiency = \frac{P_{max}}{P_{in}} \times 100$$

$$FF = \frac{P_{max}}{I_{sc}V_{oc}} \times 100$$

The observed parameters are given in table 2 below for ZnO and CIGS-ZnO Composite thin films.

Table 2 Parameters for C4 and ZnO film

Parameters	V_{oc}	I_{sc}	V_m	I_m	FF	Efficiency
ZnO	0.22 [V]	0.027 [mA]	0.12 [V]	0.012 [mA]	0.24	0.004%
CIGS-ZnO (C4)	0.36 [V]	0.106 [mA]	0.24 [V]	0.050 [mA]	0.34	0.04%

CONCLUSION

We synthesise the ZnO and CIGS -ZnO composite thin film by Spray pyrolysis technique.The XRD and SEM analysis confirms the formation of ZnO andCIGS-ZnO thin film. Then we investigate the effect of CIGS concentration on the absorption spectrum. In the study of absorption spectrum we found C4 film shows significant change in absorption in visible spectrum region. Band gap is calculated for ZnO and C4 film the value of band gap of C4 is lower than ZnO thin film. From this result C4 film is selected for comparison of PEC performance with ZnO thin film. The efficiency is calculated using PEC performance and it is found that C4 film shows high efficiency than ZnO thin film. In conclusion, the addition of CIGS nanoparticale increase the efficiency in PEC performance.

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REFERENCE

1. Bouabdelli MW, Rogti F, Maache M, Rabehi A, Performance enhancement of CIGS thin-film solar cell, Optik (2020).
2. P. Jackson, D. Hariskos, R. Wuerz, O. Kiowski, A. Bauer, T. Magorian Friedlmeier, et al., Properties of Cu(In Ga)Se2 Solar Cells with New Record Efficiencies up to 21.7%, Physica Status Solidi Rapid Research Letters,(2015) vol. 9, no. 1.
3. A.Ashour, M.A.Kaid, N.Z.El-Sayed,A.A.Ibrahim, Physical properties of ZnO thinfilms deposited by spray pyrolysis Appled Surface Science 2006 vol. 252
4. J. L Heerden, R Swanepoel XRD analysis of ZnO thin fim prepared by spray pyrolysis Thin solid films(1997) vol. 299.
5. F.Zahedi ,R.S. DAriani, S.M.Rozati Effect of substrate temperature on the properties of ZnO thin films prepared by spray pyrolysis Material Science in semiconductor processing (April 2013) vol. 16 issue 2.
6. Dong-Yeup Lee, Sejun park, JunHo Kim Structural analysis of CIGS film prepared by chemical spray deposition.Current applied science (jan 2011) vol.11.

Laboratory Investigation to Enhance Strength Parameters of Concrete Pavement using A Sustainable Approach

Mane, P S
✉ pranalismane2000@gmail.com

Pawar, P M
✉ pawarpm@sveri.ac.in

Limkar, C R
✉ crlimkar@coe.sveri.ac.in

Jadhav, R P
✉ rpjadhav@coe.sveri.ac.in

Devmare N B
✉ nanditabdevmare@coep.sveri.ac.in

Dept. of Civil Engineering
SVERI's College of Engineering
Pandharpur, Maharashtra

ABSTRACT

The increasing demand for infrastructure development, propelled by population growth, has resulted in increased reliance on aggregates and cement, contributing to elevated levels of carbon emissions and intensified resource extraction. This research focuses on advancing the sustainability of concrete by incorporating fly ash, silica fumes, and revised coarse aggregates. Concrete batches with a consistent water-cement ratio of 0.4, underwent thorough evaluation through compressive strength tests after 7, 14 and 28 days of curing. The quantity of revitalized aggregates was varied at 0% to 30% with natural aggregates, and the replacement levels for OPC 53 with Fly Ash ranged from 0% to 25%, and Silica Fume was added at 3% and 15% of the cement weight. The concrete was cured for 7 and 28 days, following a design mix of the M40 type. The maximum compressive strength observed after 7 days of curing was 39.56N/mm², and at the end of the 28-day curing period, it increased to 56.67 N/mm². The study concluded that the optimum percentage of replacement for maintaining compressive strength was achieved after a 28-day curing period, as further partial replacements tended to significantly change the strength.

***KEYWORDS** : Fly ash, Silica fume, RCA-revitalized coarse aggregate, Compressive strength test.*

INTRODUCTION

Choosing a material that adheres well to other materials is essential for the development of a sturdy structure. It is also critical to select environmentally friendly materials that do not require extensive excavation. This study examined the use of waste from several industries, including silica fume, ash from power plants, and recycled materials from former construction sites. They incorporate some of these waste products into standard materials instead of using them completely to observe how they impact the building material's strength and other characteristics. The purpose and materials chosen for a structure determine its costs. This study investigates the effects of varying the proportions of materials such as cement, ash, silica, sand, and recycled materials on building strength and cost. Because silica fume and ash are more readily available and act as supplimentory cementitious material, which is good at binding things together, they are gradually taking on the role of cement. The purpose of this study is to determine how the combination of various waste materials affects the durability and strength of the structure. The objective is to find a way to construct affordable and environmentally friendly products.

G. Murali [1] highlights the environmental benefits of recycling construction waste but notes that using recycled aggregate in concrete reduces its strength. Amlathe [2] investigated the impact of recycled aggregates, fly ash, and silica fumes on concrete strength and found that varying proportions affected the compressive strength. Gopal [3] explored the resistance of geopolymer concrete to acid solutions and demonstrated its superior strength and mass retention compared with traditional concrete. Ranjodh Singh [4] addresses environmental concerns in cement production by partially substituting silica fume and recycled concrete aggregates, examining their effects on concrete strengths. Ajay et al. [5] discussed the use of microsilica (silica fume) in concrete to enhance the compressive strength with different percentages of substitution. Mustapha [6] examined the viability of using fly ash and silica fume as supplementary cementing materials in self-compacting high-performance concrete, achieving a higher compressive strength with specific replacements. Wagih et al. [7] explored the potential of recycled concrete aggregate in structural concrete to address Egypt's increasing construction and demolition waste, noting its value but potential decrease in concrete quality compared to natural aggregate concrete. Falmata [8] studied self-compacting concrete with fly ash and silica fume and achieved improved strength with less cement. Seonguk Hong [9] proposes a non-destructive method using ultrasonic pulse velocity to estimate concrete strength over time. G. Karaiskos [10] reviews ultrasonic pulse velocity and other non-destructive tests, highlighting an innovative approach with embedded transducers. Lawson [11] explores the relationship between concrete compressive strength and ultrasonic pulse velocity, considering different mixtures. T. H. Panzera [12] demonstrated the versatility of ultrasonic pulse velocity in assessing various aspects of cement composites. Ndagi [13] evaluated the reliability of Ultrasonic Pulse Velocity testing for concrete quality, and suggested complementary tests. Kalyan [14] used ultrasonic pulse velocity to assess the impact of cracks on concrete strength by comparing the surface and interior cracks.

METHODOLOGY

Materials

Cement

Concrete is produced by combining sand, gravel, and cement; adherence to IS:12269-1987 ensures OPC-53 meets the prescribed strength standards in the Indian Standard Specifications after 28 days.

Fly Ash (FA)

Fly ash, a coal power plant byproduct, boosts cement-based products in road construction, endorsed by the Federal Highway Administration for applications such as embankments and mine fills.

Silica Fume

Silica fume, a byproduct of silicon production, enhances concrete strength and durability and requires careful handling during placement, finishing, and curing by contractors.

Revitalized Coarse Aggregate

Revitalized Coarse Aggregates (RCAs), obtained by crushing concrete from demolition, act as sustainable alternatives to natural aggregates, contributing to eco-friendly construction in various applications.

Mix proportion and specimen

i. A detailed experimental process involved the creation of Twenty-Seven unique concrete mixes, each featuring different replacement levels: 5% to 25% for fly ash (FA) substituting cement, 3% to 15% for silica fume (SF) replacing cement, and 0% to 30% for revitalized coarse aggregate replacing regular coarse aggregate. The decision to maintain a constant water-to-cement (w/c) ratio of 0.45 was deliberate to ensure consistency and enhance the overall strength and durability of the resultant concrete. Importantly, the inclusion of silica fume (SF) in the mixes served the dual purpose of improving the concrete's pore structure and acting as a filler to augment its density.

ii. A comprehensive summary of the distinct mixture proportions is compiled for easy reference. The assessment of these concrete mixes focused on measuring the compressive strength using standard 150 mm × 150 mm × 150 mm concrete cubes. These cubes underwent a controlled curing process in water at a temperature of 20 ± 5°C for 7 and 28 days. This systematic approach allowed for a detailed examination of the influence of different replacement levels on the strength and durability of concrete across various curing periods.

TEST METHODS

1. **Material Selection:** Procure materials such as OPC grade 53, Fly Ash, Silica Fume, and Recycled Concrete Aggregates (RCAs).
2. **Concrete Mix Design:** Design mixes with varying percentages of supplementary materials and RCAs, maintaining a 0.4 water-cement ratio. The proportions were prepared to ensure uniform mixing. Cast specimens with different replacement levels of fly ash, silica fumes, and RCAs. We prepared M40 grade concrete.
3. **Curing Conditions:** Implementing controlled curing conditions to optimize concrete strength and durability. This involves subjecting the specimens to: During the first seven days, it is important to keep the concrete wet and at a steady temperature. This helps the concrete strengthen from the beginning, making it sturdy. Over the next 14 days, this process continued to strengthen the concrete. Maintaining this care for 28 days ensures that the concrete becomes as strong as possible, with the right structure and lasting performance.
4. **Testing:** Conduct a comprehensive range of tests, including compressive strength tests, which helps determine if the concrete is robust enough for construction and assesses its ability to withstand pressure without breaking. Durability assessments, such as ultrasonic pulse velocity tests, involve sending sound waves through concrete to evaluate its strength and quality. By measuring the speed of these sound waves, we can determine the integrity of concrete without causing any harm, ensuring that it meets the required strength and safety standards for use in construction.

Fig. 1. Casting of cubes

Fig. 2. Compression-testing machine

Fig. 3. Ultrasonic Testing Equipment

RESULT AND DISCUSSION

Compressive strength based on different proportions of Fly Ash (FA), Silica Fume (SF), and Recycled Concrete Aggregates (RCA) in the concrete mix the compressive strength outcomes for various mixes are Mix 1, comprising 6% Fly Ash, 3% Silica Fume, and 6% RCA, demonstrated a concrete compressive strength of 46.66 MPa. The following mixes, featuring different proportions of FA, SF, and RCA, exhibited varying strengths, revealing the complex interplay of these components on concrete performance. For instance, Mix 3, with 5% Fly Ash, 9% Silica Fume, and 18% RCA, achieved the highest compressive strength at 56.67 MPa. In contrast, Mix 6, incorporating 5% Fly Ash, 15% Silica Fume, and 30% RCA, displayed a comparatively lower strength of 31.55 MPa. These results underscore the intricate relationship between the composition of supplementary materials and recycled aggregates, shedding light on the optimization challenges for sustainable and robust concrete formulations.

Fig. 4. Compressive Strength Graph

From the fig. 4. Graph it is observed that the UPV is more than 4000 m/s for mixture proportions. For instance, Mix 6, with 5% Fly Ash, 15% Silica Fume, and 30 % RCA, and Mix 16, with 15% Fly Ash, 15% Silica Fume, and 12% RCA achieved the highest velocity at 5172 m/s and 5361 m/s resp which indicates high strength and durability of the specimen.

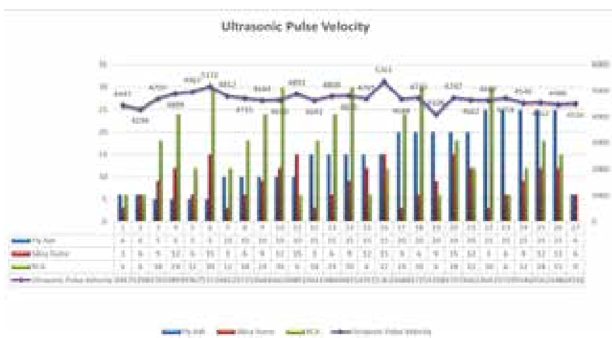


Fig. 4. UPV Test Result Graph

CONCLUSION

Following the substitution of a portion of OPC with FA Silica fume and the replacement of natural aggregates with varying proportions of recycled aggregates, the results indicated the following.

- A total of 27 sets were established to explore various mix combinations, all of which exhibited satisfactory outcomes at both the 7 and 28-day intervals.
- After 7 days, the highest compressive strength recorded was 39.56 N/mm2, while after 28 days, it reached 56.67 N/mm2. These strengths were observed in a mix containing 18% recycled aggregate, 5% fly ash, and 9% silica fume. In comparison, plain concrete demonstrated strength of 28 N/mm2 at 7 days and 45.93 N/mm2 at 28 days.
- Comparing groups, most show similar compressive strength, while some have slightly lower values. However, replacing more than 20% of recycled aggregate with natural aggregate, and replacing more than are 15% for fly ash, 9% for silica fume in cement results in decreased compressive strength.
- Cost reduction has been achieved through the replacement of cement and coarse aggregate with fly ash and recycled aggregate, accompanied by the addition of silica fume.

REFERENCES

1. Murali, G., Vardhan, C. V., Rajan, G., Janani, G. J., Jajan, N. S., & Sri, R. R. (2012). Experimental study on recycled aggregate concrete. Int. J. Eng. Res. Appl, 2(2), 407-410.
2. Amlathe, V., & Shrivastava, V. K. Effects of Fly Ash and Silica Fumes with Recycled Aggregates on Strength of Concrete.
3. Madhan Gopal, K. and Naga Kiran. B. “Investigation on Behaviour of Fly Ash Based Geopolymer Concrete in Acidic Environment”, International Journal of Modern Engineering Research (IJMER), Vol.3, No.1, pp 580-586, 2013.
4. Singh, R., & Arora, S. (2017). Influence of Silica Fume & Recycled Concrete Aggregates on Mechanical Properties of Concrete. International Journal of Engineering Technology, Management and Applied Sciences, 5(1).
5. Ajay, V., Rajeev, C., & Yadav, R. K. (2012). Effect of micro silica on the strength of concrete with ordinary Portland cement. Res J Eng Sci ISSN, 2278, 9472.
6. Mustapha, F. A., Sulaiman, A., Mohamed, R. N., & Umara, S. A. (2021). The effect of fly ash and silica fume on self-compacting high-performance concrete. Materials Today: Proceedings, 39, 965-969.
7. Wagih, A. M., El-Karmoty, H. Z., Ebid, M., & Okba, S. H. (2013). Recycled construction and demolition concrete waste as aggregate for structural concrete. HBRC journal, 9(3), 193-200.

8. Yaman, I. O., Inci, G., Yesiller, N., & Aktan, H. M. (2001). Ultrasonic pulse velocity in concrete using direct and indirect transmission. ACI Materials Journal, 98(6), 450.

9. Hong, S., Yoon, S., Kim, J., Lee, C., Kim, S., & Lee, Y. (2020). Evaluation of condition of concrete structures using ultrasonic pulse velocity method. Applied Sciences, 10(2), 706.

10. Karaiskos, G., Deraemaeker, A., Aggelis, D. G., & Van Hemelrijck, D. (2015). Monitoring of concrete structures using the ultrasonic pulse velocity method. Smart Materials and Structures, 24(11), 113001.

11. Lawson, I., Danso, K. A., Odoi, H. C., Adjei, C. A., Quashie, F. K., Mumuni, I. I., & Ibrahim, I. S. (2011). Non-destructive evaluation of concrete using ultrasonic pulse velocity. Research Journal of Applied Sciences, Engineering and Technology, 3(6), 499-504.

12. Panzera, T. H., Christoforo, A. L., Cota, F. P., Borges, P. R., & Bowen, C. R. (2011). Ultrasonic pulse velocity evaluation of cementitious materials. Advances in composite materials-analysis of natural and man-made materials, 411-436.

13. Ndagi, A., Umar, A. A., Hejazi, F., & Jaafar, M. S. (2019, November). Non-destructive assessment of concrete deterioration by ultrasonic pulse velocity: A review. In IOP Conference Series: Earth and Environmental Science (Vol. 357, No. 1, p. 012015). IOP Publishing.

14. Kalyan, T., & Kishen, J. C. (2013). Experimental evaluation of cracks in concrete by ultrasonic pulse velocity. Proceedings of the APCNDT.

Use of E-Waste in Concrete Paver Block

Hrishikesh Bhave
Department of Mechanical Engineering
VPM's Maharshi Parshuram College of Engineering
Velneswar, Maharashtra
✉ hrishikesh.bhave@vpmmpcoe.org

Divya Jadhav
Department of Civil Engineering
VPM's Maharshi Parshuram College of Engineering
Velneswar, Maharashtra

ABSTRACT

Plastic waste has become a significant environmental concern globally, with its disposal posing serious challenges. In response, the utilization of recycled plastic in construction materials has gained attention as a sustainable solution. This abstract focuses on the development and utilization of plastic paver blocks as an eco-friendly alternative to traditional paving materials. These blocks are manufactured by incorporating recycled plastic alongside traditional construction aggregates, resulting in durable, cost-effective, and environmentally friendly paving solutions. The abstract discusses the manufacturing process, properties, and potential applications of plastic paver blocks, emphasizing their role in mitigating plastic pollution and contributing to sustainable infrastructure development. Additionally, the abstract explores the economic and environmental benefits associated with the adoption of plastic paver blocks, including reduced carbon footprint, conservation of natural resourses, and promotion of circular economy principles. Overall, plastic paver block represent a promising a venue for addressing both plastic waste management and sustainable construction needs, offering a viable solution for enhancing the resilience and sustainability of urban infrastructure.

KEYWORDS *: E-waste, Plastic paver block, Recycling, Aggregates.*

INTRODUCTION

The electronics industry is undoubtedly the largest and most innovative sector of its kind globally. However, with the staggering amount of electronic items shipped annually, a concerning issue arises post-usage: electronic waste. E-waste comprises hazardous heavy metals, acids, toxic chemicals, and non-degradable plastics. Unfortunately, a significant portion of e-waste ends up either dumped, burned, or exported to recyclers, with about 75% of it left uncertain regarding its fate. This uncertainty includes possibilities like refurbishment, re-manufacture, reuse, or simply being left as junk, cluttering spaces in homes, apartments, and industrial facilities.

Historically, many e-recyclers have exported toxic materials such as leaded glass, circuit boards, and mercury lamps, mainly to regions like China, Africa, and India. However, the dismantling process of e-waste is labor-intensive and often hazardous, involving practices like shredding, tearing, and burning. In countries like China and parts of India, where tons of e-waste accumulate, this process releases harmful smoke and dust particles containing carcinogens and other hazardous chemicals, leading to severe health issues like respiratory and skin diseases.

The extraction of valuable metals from circuits, such as gold, platinum, and cadmium, involves burning the components. However, this process releases toxic emissions due to the presence of PVC and PCB coatings on wires, as well as carcinogenic carbon particles from toner cartridges. Despite the health risks, poverty drives some regions, like Guangzhou in China and Ghana, to continue handling e-waste, with China alone receiving about 70% of the world's e-waste by 2007.

The increasing accumulation of e-waste poses a significant threat to public health and environmental well-being. India, for instance, ranks fifth globally in e-waste generation, with approximately 2 million tons generated annually and an undisclosed amount imported from other countries. To address this issue, innovative projects aim to incorporate e-waste into construction materials like cement for paver blocks and tiles. By utilizing e-waste plastic in varying proportions with cement, sand, and coarse aggregate, these projects strive to mitigate the accumulation of nondegradable waste while offering cost-effective alternatives to conventional concrete products.

LITERATURE REVIEW

The study evaluated 75 samples across 5 batches with varying plastic:sand ratios. Results showed that PB2 batch had the highest compressive and tensile strengths, with decreased performance in subsequent batches due to increased sand content. Water absorption increased with sand content due to more voids. PB2 batch exhibited the highest impact resistance. LDPE plastic with a ratio of 1:3 showed optimal results. LDPE waste used was 5-7mm with a specific gravity of 0.92. Mechanical properties were not significantly affected by plastic waste color.[1]

The analysis concludes that waste plastics can effectively enhance pavement block production for rigid pavements. With 20% recycled plastics, the modified blocks maintain compressive strength comparable to conventional ones. This approach reduces construction costs, mitigates ecological burdens of plastic disposal methods like landfilling and incineration, and decreases block weight by 15%. Plastic pavement blocks prove economical and advantageous over concrete ones. Ultimately, utilizing recycled plastics in pavement blocks offers a sustainable solution to plastic disposal, significantly reducing environmental plastic pollution.[2]

Plastic paving blocks, designed to reduce pollution, match concrete counterparts in appearance and interlocking capability. However, their lower strength restricts heavy traffic use. Ideal for gardens and footpaths, they're also employed in road infrastructure like leaning stones and side guards. Yet, with over 50% plastic content, they exhibit higher water absorption, exceeding 2%.[3]

Utilizing shredded hospital plastic waste in concrete offers various benefits: reducing land requirement for plastic dumping, lowering greenhouse gas emissions via flue gas conversion, and decreasing concrete unit weight. Optimal replacement at 10% maintains concrete properties and compressive strength, with cost-effectiveness improving as plastic content increases in paving blocks.[4]

After curing, both regular and plastic concrete blocks are tested using Compression Testing Machine (CTM) to determine their compressive strength. Load is applied gradually until failure, with results indicating plastic blocks have higher strength than concrete ones. Plastic blocks exhibit similar finishing and appearance to concrete, making them suitable for heavy traffic areas like parks and footpaths. Utilizing waste plastic in block manufacturing aids in waste disposal Overall, plastic paving blocks offer a viable solution to reducing pollution, providing durable infrastructure, and effectively managing plastic waste.[5]

The materials used in the study include aggregates, cement, water, and plastics, with aggregates tested for specific gravity and other properties. Ordinary Portland cement of 43-grade and IS: 456 – 2000 water were employed. Non-degradable plastics, primarily High Density Polyethylene (HDPE), were powdered for use. M20 concrete with waste plastics replacing aggregates at varying percentages was casted into 200 mm X 200 mm X 60 mm paver blocks and tested for strength at 7, 14, and 21 days. Lab tests assessed physical properties of cement, plastics, and aggregates, while paver blocks underwent curing post-casting.[6]

Plastic waste, M-Sand, and quarry dust were utilized to cast paver blocks with varying mix ratios. The preparation process involved melting plastic, adding sand, molding, and drying. Compressive strength and water absorption tests were conducted, revealing plastic paver blocks outperform ordinary blocks in both strength and water absorption, making them a promising alternative for construction.[7]

This comprehensive study focuses on the properties of ordinary Portland cement (OPC) of 43 grade and aggregates, crucial components of concrete. OPC conforms to IS 8112:1989 and is classified into 33, 43, and 53 grades based on strength. Sieve analysis evaluates aggregate gradation, distinguishing between coarse and fine fractions. The Fineness Modulus (F.M.) indicates material coarseness. Compressive strength tests reveal OPC's strength at 28 days. This meticulous investigation ensures the selection of suitable materials for concrete production, crucial for maintaining structural integrity and durability in construction projects.[8]

Compressive strength tests were conducted on conventional and paving components incorporating E-waste. Paver blocks, with dimensions of 270×120×60mm and 250×200×60mm, were assessed for strength at 3, 7, and 28 days. Cement bricks, made of a cement and sand mixture, offer high compression strength and durability, suitable for various construction applications.[9]

EPS (Expanded Polystyrene) is widely utilized in construction to improve properties and reduce weight/cost. Its use aids in waste management by reducing landfill space. While higher EPS percentages decrease compressive strength, an optimal 10% addition maintains strength comparable to conventional blocks. EPS also offers thermal insulation and lightweight construction benefits.[10]

The compressive strength of concrete with E-waste as partial replacement for fine and coarse aggregate is analyzed. Up to 20% replacement maintains comparable strength to reference concrete. Beyond 20%, strength decreases significantly. At 7 days, E-waste content slows strength gain, with 10% replacement showing minimal decrease. At 28 days, strength fluctuates with replacement levels.[11]

The plastic waste, LDPE (Low-Density Polyethylene), used for paver block casting was collected from the college canteen. LDPE properties include a melting point of 150°C, thermal expansion coefficient of 100-200×10^-6, and a density range of 0.910-0.940kg/m³. Sand properties reveal a specific gravity of 2.52 and fineness modulus of 2.92. OPC 53 grade cement was utilized. Test specimens were prepared by heating plastic waste, mixing with other materials, and compacting. Compressive strength tests were conducted on plastic paver blocks, and water absorption and thermal tests were performed, indicating satisfactory properties for construction use.[12] Methodology

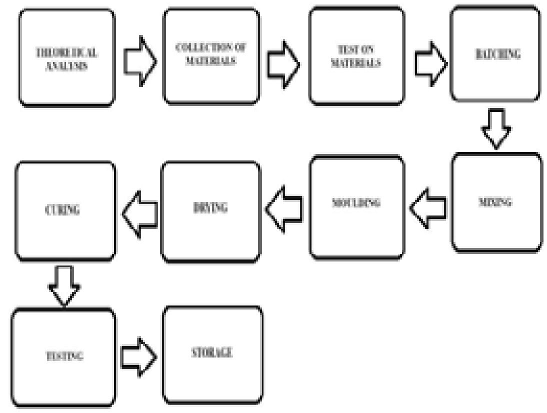


Fig 1. Block Diagram

Concrete Mix Design

For M30 Concrete

For Conventional concrete

Proportion 1:2.04:3.65

Volume of 1 paver block= 0.00123m3

Dry volume of 15 paver block=0.028m3

Therefore Quantity of Materials is as follows

Cement :9.268 kg

Sand : 19 kg

Coarse Aggregate :34 kg

Water =6 litres

For M30 Concrete

For concrete with plastic

Proportion 1:2.04:3.29

Volume of 1 paver block= 0.00123m3

Dry volume of 15 paver block=0.028m3

Therefore Quantity of Materials is as follows

Cement :9.268 kg

Sand : 19 kg

Coarse Aggregate :30.6

Plastic = 10% of Coarse Aggregate=3.4 Water =6 litres

RESULTS AND CONCLUSION

SR. NO. Duration	Average weight of conventional paver block	Average weight of E-waste paver block	Average compressive strength of conventional paver block	Average compressive strength of E-waste paver block
3 Days	3.29	3.21	12.09 N/mm^2	8.31 N/mm^2
7 Days	3.34	3.28	19.39N/mm^2	16.083 N/mm^2
14 Days	3.33	3.22	26.42N/mm^2	19.523 N/mm^2
28 Days	3.33	3.33	29.97N/mm^2	26.006 N/mm^2

REFERENCES

1. Aditya Surkar1, Arpit Bele2, Ashrut Satone3, Pritam Gupta4, Samiksha Astonkar5, Tanuja Nahate 6, Milind Nikhar7 Study on Effects of Plastic Waste in Paver blocks © June 2021| IJIRT | Volume 8 Issue 1 | ISSN: 2349-6002

2. Abdul Rahiman. P. H>1, Danish. P K 2, Fathimath Nesrin.ch Mashhoor Muhammed.c.experimental Study of Utilization of Waste Plastic Bags in Pavement Blocks International Journal of Scientific & Engineering Research Volume 10, Issue 3, March-2019 ISSN 2229-5518.

3. Anshul Vishwakarma1and Mr. Praveen Singhai1 A Review of analysis of Paver Block Containing with Recycled Plastic with Different parameters International Journal of Research Publication and Reviews, Vol 3, no 8, pp 1939-1941, August 2022

4. Athira M. Binu1, Amrutha S. Vinod2, Sethuraj P.3, Akil S.4 Experimental study on the replacement of coarse aggregates with recycled hospital plastic waste in paver blocks Binu Athira M. et al.; International Journal of Advance Research and Development

5. Somnath Shegar, 2 Priyanka Nalwade, 3 Pratiksha Mohite, 4Mayuri Bendre,Shweta Desai, Mr. Pawar S.B Waste Plastic Used In Paving Block With ReplacementOf Fine Aggregate International Research Journal of Engineering and Technology (IRJET)

6. Rahul Mane1, Shivani Rayewar2, Swapnil Katageri3, Dr. N. K. Patil Use Of Plastic Waste as A Partial Replacement of Aggregate in Paver Blocks International Research Journal of Engineering and Technology (IRJET).

7. Prof. Amit Bhovate*1, Abhishek Suryawanshi*2, Sachin Sathawane*3, Latasha Channe*4, Juhi Ramteke*5, Akanksha Meshram*6, Sonal Pantawane*7, Lina Burle*8 Waste Plastic Use in Paver Block International Research Journal of Modernization in Engineering Technology and Science

8. S. Sachdev1, L. Yadav2, P. Jain3 Study of Paver Block using E-Waste International Journal of Research in Engineering, Science and Management (IJRESM).

9 S. Prakash Chandar1, N. Nasurudeensha2,* and S. Manikandaprabhu3 Effects of Electronic Waste in Manufacturing of Building Masonry and Paving Components Vol. 12 | No. 2 |749 - 753| April - June | 2019 ISSN: 0974-1496 | e-ISSN: 0976-0083 | CODEN: RJCABP http://www.rasayanjournal.com http://www.rasayanjournal.co.in

10. Anupama U, Assistant Professor Sadhasivam Literature Review on Utilization of Waste EPS in Paver Blocks International Journal of Scientific Research & Engineering Trends Volume 6, Issue 5, Sept-Oct-2020, ISSN (Online): 2395-566X

11. Anoop Singh Dept. of Civil Engineering SHIATS Allahabad, India Vikas Srivastava Dept. of Civil Engineering SHIATS Allahabad, India Utilisation of E-waste in Concrete - An Experimental Investigation International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181 Published by, www.ijert.org ISNCESR-2015 Conference Proceeding

12. 1Tejas Anil Bhamare, 2Dhanshree Bhimrao Pawar Use of Waste Plastic in Paver Block © 2021 IJCRT | Volume 9, Issue 6 June 2021 | ISSN: 2320-2882

An Investigation into the Viability of Various Substitutes for River Sand and the Impact of Aggregate Gradation on Improving Concrete Mixes

Raut, D A
M.Tech Scholar
✉ dhanajiraut95@gmail.com

Limkar, C R
Assistant Professor
✉ crlimkar@coe.sveri.ac.in

Bhusnar , V D, Khandagale, G A
Gaikwad A G
UG Students
✉ vishvajitbhusnar55@gmail.com
✉ ganeshkhandagale614@gmail.com
✉ dakashgaikwad1809@gmail.com

Dept. of Civil Engineering
SVERI's College of Engineering
Pandharpur, Maharashtra

ABSTRACT

This research examines the significant role of aggregate gradation in optimizing concrete compressive strength while maintaining workability with various combinations of gradations ranging from 60-40 to 40-60–aggregates. The choice of aggregate gradation greatly influences concrete performance, making it a crucial consideration for engineers and producers in fulfilling project-specific requirements. The study comprises extensive experimentation with different aggregate gradations in concrete mixtures, focusing on evaluating their compressive strengths and outcomes. The primary objectives involve determining the most optimal aggregate gradation for maximizing compressive strength, comparing the effects of various aggregate gradations on concrete strength, and assessing their interaction with workability. The experimental investigation involved two stages. First, the properties of cement, coarse aggregates, fine aggregates, slag sand, and M sand were analyzed for their physical and mechanical characteristics. Subsequently, following the M-25 grade standards per IS10262-2019, mix designs were implemented.

The results demonstrate promising findings, particularly achieving an average compressive strength of 41 MPa for M25 grade concrete using a blend of 50% slag sand, 50% M sand, and 50:50 gradations for 20&10 mm coarse aggregate. These results suggest a substantial improvement in strength, providing valuable insights into an optimized aggregate gradation mix that satisfies grade requirements.

KEYWORDS *: M-Sand, Slag sand, River sand, 6mm aggregate, Gradation.*

INTRODUCTION

Concrete plays a pivotal role in the construction industry, and the availability of suitable aggregates, particularly river sand, is crucial for its production. In India, the demand for construction sand has surged exponentially in recent years, driven by rapid urbanization, infrastructure development, and population growth. However, the overexploitation of riverbeds to meet this demand has led to severe environmental consequences, including erosion, depletion of the water table, and ecological imbalance.

Acknowledging the pressing need for sustainable alternatives, this study aimed to evaluate the suitability of alternative materials to river sand in concrete pavements to enhance concrete mixes. By exploring these alternatives, we sought to address the challenges posed by the scarcity of river sand and promote sustainable construction practices in India.

The crisis of sand scarcity in India has been emphasized by recent statistics. According to a report by the United Nations Environment Programme (UNEP), India ranks second globally in terms of sand consumption, with an approximated annual consumption of 1.35 billion metric tons. By 2025, it is projected that India's sand demand will reach a staggering 1.5 billion metric tons annually. However, the availability of river sand is limited, and numerous rivers across the country are facing depletion due to extensive sand mining.

In response to this scarcity, researchers and industry experts have explored alternatives. Crushed stone dust, quarry dust, manufactured sand, and recycled aggregates have emerged as potential substitutes for river sand in concrete production. These alternatives have the potential to fulfill the necessary standards of strength, durability, and workability while reducing the environmental impact associated with sand extraction.

The objective of this study was to bridge the knowledge gap with regard to the feasibility of alternative materials for concrete pavements in India. By conducting extensive laboratory experiments and evaluating the physical, mechanical, and chemical properties of various alternatives, we aimed to determine their efficacy in enhancing concrete mixes. Additionally, this study sought to assess the performance of concrete pavements incorporating these alternatives, considering factors such as load-bearing capacity, abrasion resistance, and crack formation.

The findings of this study hold significant implications for the construction industry in India. They provide valuable insights for engineers, architects, and policymakers, enabling them to make informed decisions regarding the selection and design of concrete mixes. By adopting sustainable alternatives to river sand, India can address the environmental challenges associated with sand mining and ensure the availability of construction materials for future development. Previous research by B. V. Venkatarama Reddy et al. [1] evaluated manufactured sand (M-sand) as a substitute for river sand in concrete and mortar. They found that M-sand exhibited similar physical properties to river sand and led to higher compressive strength in both mortar and masonry. Concrete made with M-sand showed a notable increase in compressive strength compared to that made with natural sand. Similarly, H. M. A. Mahzuz et al. [2] investigated the potential of stone powder from crushing zones as an alternative to river sand in mortar and concrete. Their experiments revealed that mortar containing stone powder achieved higher compressive strength, and concrete incorporating stone powder also exhibited a significant increase in strength compared to river sand concrete.

Priyanka A. Jadhav et al. [3] investigated the hardened properties of mortar with varying percentages of M-sand replacement for river sand. They observed marginal improvements in the compressive strength, with the highest strength achieved at 50% replacement and specific mix ratios. Leonardo F. R. Miranda et al. [4] focused on recycled sand from construction sites for use in bedding mortar. They proposed suitable proportions of recycled aggregates in mortar production to achieve adequate bending and shear strength. Elavenil et al. [5] explored the properties of concrete made with M-sand as a complete replacement for river sand. Their findings indicated higher workability and compressive strength in M-sand concrete than in natural sand concrete. C. Nataraja et al. [6] investigated Granulated Blast Furnace Slag (GBFS) as a substitute for natural sand in mortar. They found that while the GBFS mortar exhibited lower initial workability, the use of a superplasticizer improved this aspect. The compressive strength at 28 days varied with the replacement percentage, with 50% replacement showing comparable results to those of natural sand. Mohammed Nadeem et al. [7] studied the replacement of industrial slag as aggregate in concrete, observing increased compressive strength values with certain replacement percentages. J. Silva, J. Brito et al. [8] assessed red-clay and ceramic waste as replacements for sand in mortar production. They found that 20% replacement led to improved strength properties and reduced water permeability.

OBJECTIVES

- To evaluate the physical properties of alternative materials (M-sand, slag sand, 6 mm) and compare them to river sand.
- To assess the physical and mechanical properties (compressive strength, flexural strength, etc.) of concrete mixes (M 25) incorporating alternative materials.

METHODOLOGY

Materials

1. To evaluate the physical properties of alternative materials (M-sand, slag sand, 6 mm) and compare them to river sand.

The goal of this research is to evaluate the physical characteristics of alternative materials, such as M-sand, slag sand, and 6 mm aggregates, relative to conventional river sand. To accomplish this goal, a thorough review of the literature was conducted to identify important parameters and procedures. The samples of each material were obtained and prepared based on the pertinent standards. The experimental process will involve tests on particle size distribution, specific gravity, moisture content, and bulk density. All data collected will be analyzed using statistical methods to compare the materials. The outcomes will be presented in tables and graphs, followed by a detailed discussion of the results, conclusions, and suggestions.

2. To assess the physical and mechanical properties (compressive strength, flexural strength, etc.) of concrete mixes (M 25) incorporating alternative materials

Various concrete mixes will be formulated using alternative materials while adhering to standard mix design principles. The specimens will be prepared, cast, and cured in accordance with established procedures. Subsequently, the hardened samples will undergo compressive and flexural strength tests using a suitable testing apparatus. The collected data will be analyzed statistically to evaluate the performance of the alternative material mixes compared to a conventional M 25 mix. The outcomes will be presented in tables and graphs, followed by a comprehensive discussion, conclusions, and recommendations.

3. Mix proportion and specimen

1. The study evaluated the effectiveness of alternative materials in concrete and mortar production by carefully choosing the mix proportions and specimens. The researchers examined different replacement percentages and mix ratios to determine their impact on the properties of the resulting mixtures.

Mix Proportions for Trial Number 1 Based on Aggregate in SSD Condition

Cement = 362 Kg/m^3
Water = 170 Kg/m^3

Fine aggregate (SSD) = 728 Kg/m^3
Coarse aggregate (SSD) =1225 Kg/m^3

Free water-cement ratio = 0.47

2. A comprehensive summary of the diverse mixture proportions has been prepared for easy access. The evaluation of these concrete mixes was conducted by measuring the compressive strength of standard 150 mm × 150 mm × 150 mm concrete cubes. These cubes were subjected to a controlled curing process in water at a temperature of 20 ± 5°C for 7 and 28 days. This methodical approach facilitated a thorough examination of the impact of various replacement levels on the strength and endurance of concrete across different curing durations.

TEST METHODS

1. Material Selection: Procured materials such as OPC grade 53, M-sand, Slag Sand, 6 mm sand, 10 mm, and 20 mm coarse aggregates.
2. Concrete Mix Design: Design mixes with varying percentages of M- sand, Slag Sand, 6mm sand, 10 mm and 20 mm coarse aggregates, maintaining a 0.47 water-cement ratio. The proportions were prepared to ensure uniform mixing.
3. Curing conditions: Controlling curing conditions to optimize concrete strength and durability. This involves subjecting the specimens to the following: During the first seven days, it is important to keep the concrete wet and at a steady temperature. This helps concrete to strengthen from the beginning, making it sturdy. Over the next 14 d, this process continued to strengthen the concrete. Maintaining this care for 28 d ensures that the concrete becomes as strong as possible, with the right structure and lasting performance.
4. Testing: Conduct a comprehensive range of tests, including compressive strength tests, which help determine if the concrete is robust enough for construction and assess its ability to withstand

pressure without breaking. Durability assessments such as ultrasonic pulse velocity tests involve sending sound waves through concrete to evaluate its strength and quality. By measuring the speed of these sound waves, the integrity of concrete can be determined without causing any harm, ensuring that it meets the required strength and safety standards for use in construction.

Fig. 1. Casting of cubes

Fig. 2. Compression-testing machine

Fig. 3. Slag Sand

Fig. 4. M sand

RESULT AND DISCUSSION

Proportion No	M-Sand	6mm	RIVER	SLAG	20MM	10 MM	Concrete compressive strength
1	70	30	-	-	60	40	31.67
2	70	30	-	-	50	50	38.22
3	50	-	-	50	50	50	41.48
4	-	-	50	50	50	50	35.11
5	33	-	33	33	50	50	30.22
6	-	30	-	70	55	45	35.03
7	-	20	-	80	55	45	26.67
8	-	-	40	60	50	50	26.11
9	100	-	-	-	60	40	31.33

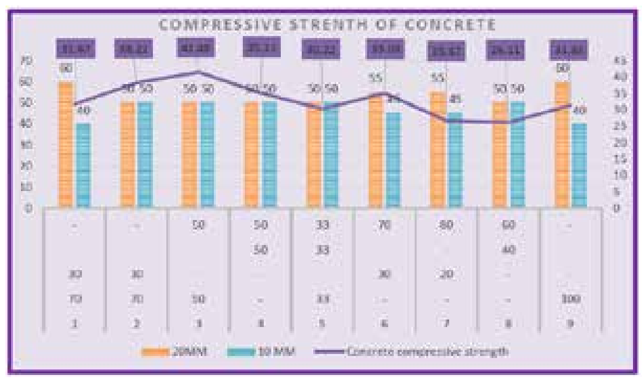


Fig. 5. Compressive Strength Graph

- From the fig. 5. Based on the results, Proportion 3, which consists of slag as the primary aggregate, appears to yield the highest compressive strength of 41.48 MPa. However, the use of slag may be subject to availability and specific project requirements.
- Alternatively, Proportion 2, which includes a high percentage of M-Sand, also demonstrates competitive compressive strength at 38.22 MPa. M-Sand is often readily available and offers advantages in terms of consistent quality and reduced environmental impact.

- Therefore, depending on factors such as material availability, project constraints, and cost considerations, Proportion 2 (M-Sand 70%, 6mm Aggregate 30%) could be considered an optimum proportion for achieving high compressive strength in concrete mixes. However, further analysis considering other factors beyond compressive strength would be necessary to determine the most suitable proportion for a specific project.

CONCLUSION

The analysis of the compressive strength results for various concrete mix proportions provides valuable insights into the performance of different aggregate compositions. The following is a detailed conclusion based on these data.

1. Effect of Aggregate Composition

- The data demonstrate the significant impact of the aggregate composition on the concrete compressive strength. Mixtures containing alternative materials, such as slag and M-sand, exhibit competitive compressive strengths compared to traditional river sand mixes.

2. Performance of Alternative Materials.

- Proportion 3, which included slag as the primary aggregate, demonstrated the highest compressive strength of 41.48 MPa. Proportion 2, comprising a high percentage of M-Sand, also achieved a competitive compressive strength of 38.22 MPa.

3. Optimization Potential:

- Mixtures with higher percentages of fine aggregates, such as M-sand, generally exhibit higher compressive strengths. However, Proportion 3 with slag showed promising results, indicating the potential for optimizing concrete mixtures using alternative materials.

4. Consideration of the Project Requirements

- Selection of the optimum mix proportion depends on various factors such as material availability, project constraints, and cost considerations. While Proportions 3 and 2 demonstrate high compressive strengths, the availability and cost-effectiveness of slag and M-sand must be considered for practical applications.

REFERENCES

1. B. V. Venkataram Reddy, "Suitability of manufactured sand (M-sand) as fine aggregate in mortar and concrete", CSIC Project sponsored by Department of Mine and Geology (Govt. of Karnataka), July 2011.
2. H. M. A. Mahzuz, A. A. M. Ahmed and M. A. Yusuf, "Use of stone powder in concrete and mortar as an alternative of sand", African Journal of Environmental Science and Technology, Vol. 5(5), May 2011, pp. 381-388
3. Priyanka A. Jadhav, Dilip K. Kulkarni, "Effect of replacement of natural sand by manufactured sand on the properties of cement mortar", International Journal of Civil and Structural Engineering, Volume 3, no 3, 2013.
4. Leonardo F. R. Miranda, Camila S. Constantino, Carla R. Monich and Antonio A. de M. Neto, "Use of Recycled Sand Produced at Construction Sites in Bedding Mortars", American Society of Civil Engineers Library, 2013
5. S. E. Enavenil and B. Vijaya, "Manufactured Sand, A Solution and an Alternative to River Sand and In Concrete Manufacturing", Journal of Engineering, Computers & Applied Sciences (JEC&AS), Volume 2, No.2, February 2013.
6. M. C. Nataraja, P.G. Dileep Kumar, A. S. Manu and M. C. Sanjay, "Use of granulated blast furnace slag as fine aggregate in cement mortar", International Journal of Structural and Civil Engineering Research, Volume.2, No.2, May 2013.
7. Mohammed Nadeem and Arun D. Pofale, "Utilization of Industrial Waste Slag as Aggregate in Concrete Applications by Adopting Taguchi's Approach for Optimization", Open Journal of Civil Engineering, 2012, 2, pp.96-105.
8. J. Silva, J. de Brito and R. Veiga, "Recycled Red-Clay Ceramic Construction and Demolition Waste for Mortars Production", American Society of Civil Engineers Library, 2010.

Development of Various Concrete Mixes for Self- Compacting Concrete with A Sustainable Approach

Shinde, M R, Mali, M M
U G Student
✉ madhurirshinde@coep.sveri.ac.in
✉ mayuritmali@coep.sveri.ac.in

Limkar, C R, Kokare, A B
Assistant Professor
✉ ccrlimkar@coe.sveri.ac.in
✉ abkokare@coe.sveri.ac.in

Dept. of Civil Engineering
SVERI's College of Engineering
Pandharpur, Maharashtra

ABSTRACT

This paper presents a comprehensive investigation of the development of self- compacting concrete (SCC) for sustainable construction practices. This study encompasses the preparation and testing of 15 distinct concrete mixes, each varying in the replacement of cement with environmentally beneficial materials such as fly ash, silica fume, and metakaolin. Through experimental research involving casting and testing of concrete blocks, we aimed to strike a balance between the compressive strength, workability, and environmental impact.

Our findings revealed that among the tested mixes, the combination comprising 5% Fly Ash, 3% Silica Fumes, and 3% metakaolin demonstrated the highest compressive strength of 41.33 MPa. Furthermore, this optimal mix exhibited exceptional workability, characterized by a uniform flow time of less than 8 s and a slump flow diameter ranging from 800 to 850 mm. These results underscore the feasibility of utilizing supplementary cementitious materials to enhance both the mechanical properties and sustainability of SCC, thus offering a promising avenue for eco-friendly construction practices.

***KEYWORDS** : Fly ash, Silica fume, Metakaolin, Compressive strength Test, Sustainability.*

INTRODUCTION

Self-Compacting Concrete (SCC) represents a revolutionary advancement in concrete technology that reshapes the norms of modern construction practices. Originating in response to the challenges posed by intricate architectural designs and densely reinforced structures, SCC emerged in the late 20th century, pioneered by Japanese innovators seeking materials capable of navigating complex formworks without mechanical consolidation. At its core, SCC embodies exceptional attributes that differentiate it from traditional concrete, notably, its unparalleled flowability. Through precise proportions of water, cement, and admixtures, SCC achieves a graceful, self-leveling flow into congested formwork, eliminating the need for external compaction. SCC typically comprises high- quality aggregates, cement, water, and chemical admixtures, such as superplasticizers, which are crucial for reducing the water-cement ratio while maintaining optimal workability. Beyond its flowability, SCC exhibits stable cohesion, uniformity, and resistance to segregation, safeguarding its structural integrity without the need for manual or mechanical compaction. Remarkably, SCC's strength of SCC remains uncompromised, allowing it to adapt to diverse construction applications from towering high rises to critical infrastructure components.

The benefits of SCC extend beyond technical superiority, offering substantial reductions in labor and equipment requirements. Furthermore, its ability to yield flawless surface finishes satisfies the demands of contemporary construction aesthetics. The meticulous selection and proportioning of components, coupled with advanced mix designs, underscores SCC's transformative influence of SCC on construction practices. SCC transcends its identity as mere technological innovation, embodying a paradigm shift aligned with modern construction aspirations of efficiency, sustainability, and innovation. It bridges the traditions of the past with limitless possibilities for the future, asserting itself as an indispensable element in contemporary construction endeavors. The introduction of Self-Compacting Concrete (SCC) has revolutionized the construction landscape by eliminating the need for mechanical compaction and introducing a myriad of benefits.[1] Neeraja et al. highlight the use of recycled coarse aggregate in self-compacting concrete (SCC) to promote sustainable construction and address environmental concerns.[2] Kumar et al. explore the use of industrial waste in creating sustainable construction materials, emphasizing the importance of performance-based evaluations and the potential of biological approaches.[3] Kanagaraj et al. investigate the sustainability of self-compactable lightweight geopolymer concrete (SCLGC) using Expanded Clay Aggregate, finding higher energy demand and CO2 emissions with increased SH concentration.[4] Prabhu et al.'s study explores using mining waste in self-compacting concrete (SCC) to promote sustainability in construction, addressing challenges through numerical modelling.[5] Revilla-Cuesta et al. introduce a multi-parametric classification for Self-Compacting Concrete (SCC) using sustainable raw materials, focusing on fresh properties like slump flow, viscosity, and blocking ratio.[6] Khan et al.'s research explores the use of glass powder, quartz powder, and limestone powder as Supplementary Cementitious Materials in Self-Compacting Concrete for sustainable construction. [7] The study explores the use of bone-china ceramic powder waste and granite cutting waste as substitutes for cement and natural fine aggregates in self-compacting concrete.[8] The Sustainable Preference Index (SPI) aids in selecting sustainable cementitious materials in construction, with GGBS 40% SCC having the highest SPI, making it 30.2% more sustainable. [9] The study by Kanagaraj et al. investigates the sustainability of self- compactable lightweight geopolymer concrete (SCLGC) using Expanded Clay Aggregate, finding higher energy demand and CO2 emissions with increased SH concentration.[10] The study by Azarhomayun et al. explores stability issues in self-compacting concrete, revealing that stability negatively impacts compressive strength, electrical resistance, and corrosion susceptibility.[11] The study predicts creep in self-compacting concrete beams under four-point bending stress, revealing increased limestone fineness improves mechanical performance and reduces delayed deformations, with American models being most accurate.[12] The study by Rojo-López et al. examined self- compacting concrete with limestone filler and metakaolin as partial replacements, revealing that ternary binders improved concrete's sustainable performance.[13] Wang et al. developed a method for designing self-compacting recycled aggregate concrete (SCRAC) without tedious adjustments, offering design guidance for sustainable concrete containing recycled materials.[14] CO2 mineralization enhances the strength and durability of SCC, achieving 4.3% higher compressive strength and 1.88% higher compressive strength, reducing chloride ion penetration and carbon emission.

METHODOLOGY

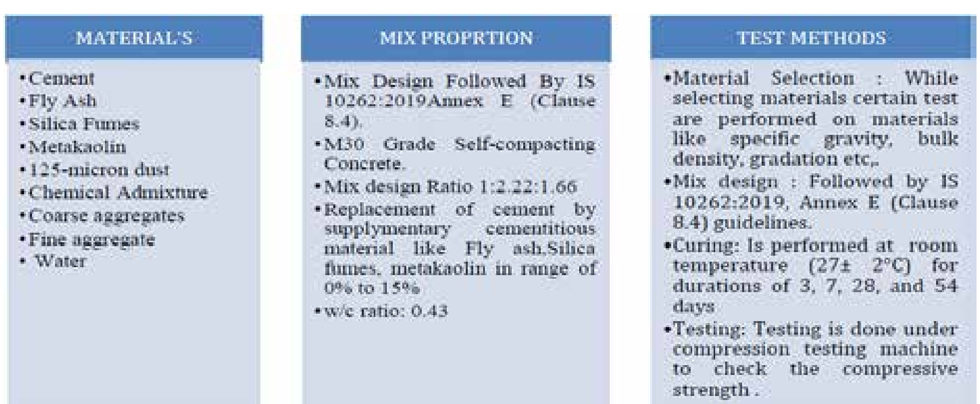


Fig.1.Flowable Concrete

Fig.2. Casting of blocks

Fig.3. Compression Testing Machine

Fig.4.After testing in CTM

RESULT AND DISCUSSION

From fig.5. The compressive strength analysis reveals that Mix 1, with 5% Fly Ash, 3% Silica Fume, and 3% Metakaolin, showed the highest strength at 37.57 MPa. Mix 13, with 15% Fly Ash and the same supplementary materials, achieved 30.67 MPa. However, Mixes 4 and 5, with 5% Fly Ash but higher Silica Fume, had lower strengths at 16.00 MPa. Higher Silica Fume content generally led to decreased strength, as seen in Mixes 4, 5, 8, and 12. These findings highlight the importance of optimizing supplementary material proportions for desired concrete strength.

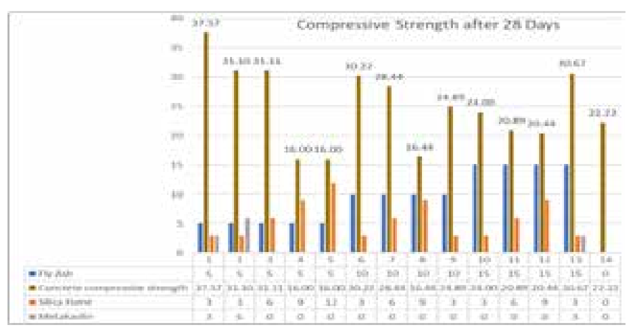


Fig.5. Compressive Strength Graph

From fig.6. The compressive strength analysis of various concrete mixes reveals that Mix 1, with 5% Fly Ash, 3% Silica Fume, and 3% Metakaolin, shows the highest strength at 41.33 MPa. Mix 7, containing 10% Fly Ash and 6% Silica Fume, also demonstrates strong performance at 31.56 MPa. Conversely, mixes lacking

Metakaolin, such as Mixes 3, 8, and 12, exhibit lower strengths. Surprisingly, Mix 14, without supplementary materials, displays a lower strength of 33.78 MPa. These results emphasize the importance of optimizing mix proportions for desired concrete performance.

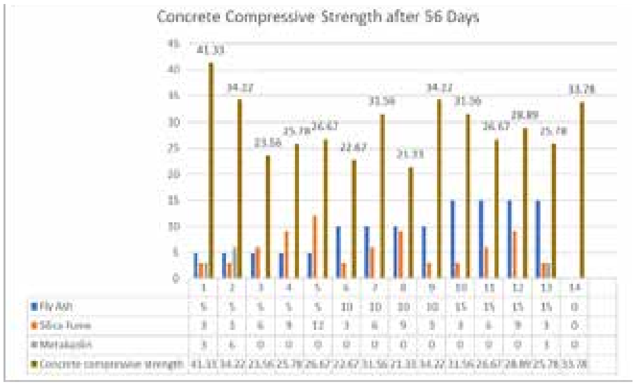


Fig.6. Compressive Strength Graph

CARBON FOOTPRINT

The carbon footprint, a measure of greenhouse gas emissions from human activities, can be reduced through sustainable practices, energy efficiency, and innovative technologies. The formula to estimate the carbon footprint of a material is generally calculated by multiplying the mass of the material by its associated carbon emission factor. The formula can be expressed as:

Carbon Footprint = Mass of Material (kg) × Carbon Emission Factor (kg CO_2/kg)

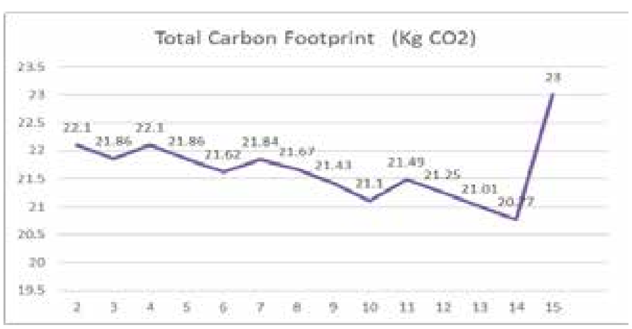


Fig.7. Carbon footprint

CONCLUSION

- Self-Compacting Concrete is Flowable, Workable Concrete .
- Replacing cement by supplementary cementitious materials like Fly Ash, Silica Fume, and Metakaolin optimizes maximum concrete strength, Mix 1 achieving the highest strength at 41.33 MPa, highlighting the critical importance of meticulous mix design in self-compacting concrete formulations.
- Substituting cement with Supplementary Cementitious Materials effectively reduces the carbon footprint associated with concrete production, showcasing a sustainable approach towards environmental conservation.

REFERENCES

1. Neeraja, V. S., & Sharma, V. (2023). An overview of fresh and mechanical properties of recycled coarse aggregate self-compacting concrete. Materials Today: Proceedings.
2. Kumar, A., Garg, M., Garg, N., Kumar, S., Rai, N., & Das, S. K. (2023). A systematic review of the mechanical and durability properties of sustainable bacterial concrete. Materials Today: Proceedings.
3. Prabhu, R. S., Anuradha, R., & Jude, A. B. (2022). Understanding the mining waste as resources in self-compacting concrete: A numerical study on sustainable construction. Resources Policy, 78, 102806.
4. Khan, M. M. H., Sobuz, M. H. R., Meraz, M. M., Tam, V. W., Hasan, N. M. S., & Shaurdho, N. M. N. (2023). Effect of various powder content on the properties of self- compacting concrete. Case Studies in Construction Materials, 19, e02274.
5. Revilla-Cuesta, V., Skaf, M., Ortega-López, V., & Manso, J. M. (2023). Multi- parametric flowability classification of self-compacting concrete containing sustainable raw materials: An approach to real applications. Journal of Building Engineering, 63, 105524.
6. Revilla-Cuesta, V., Faleschini, F., Pellegrino, C., Skaf, M., & Ortega-Lopez, V. (2022). Simultaneous addition of slag binder recycled concrete aggregate and sustainable powders to self- compacting concrete: a synergistic mechanical-property approach. Journal of Materials Research and Technology, 18, 1886-1908.

7. Gautam, L., Bansal, S., Sharma, K. V., & Kalla, P. (2023, August). Bone-china ceramic powder and granite industrial by-product waste in self-compacting concrete: A durability assessment with statistical validation. In Structures (Vol. 54, pp. 837-856). Elsevier.

8. Reddy, A. S., Kumar, P. R., & Raj, P. A. (2020). Development of sustainable performance index (SPI) for self-compacting concretes. Journal of Building Engineering, 27, 100974.

9. Kanagaraj, B., Anand, N., Praveen, B., Kandasami, S., Lubloy, E., & Naser, M. Z. (2023). Physical characteristics and mechanical properties of a sustainable lightweight geopolymer based self-compacting concrete with expanded clay aggregates. Developments in the Built Environment, 13, 100115.

10. Azarhomayun, F., Haji, M., Shekarchi, M., & Kioumarsiha, M. (2023). Investigating the Effectiveness of the Stable Measurement Tests of Self-Compacting Concrete. Construction and Building Materials, 383, 131262.

11. Chabane, A., Belebchouche, C., Bensebti, S. E., Czarnecki, S., & Boukezzoula, A. (2022). Comparison of the accuracy of regulation models for self-compacting concrete creep evaluation. Journal of Building Engineering, 59, 105069.

12. Rojo-López, G., González-Fonteboa, B., Martínez-Abella, F., & González-Taboada, I. (2022). Rheology, durability, and mechanical performance of sustainable self- compacting concrete with metakaolin and limestone filler. Case Studies in Construction Materials, 17, e01143.

13. Wang, Z., & Wu, B. (2023). A mix design method for self-compacting recycled aggregate concrete targeting slump-flow and compressive strength. Construction and Building Materials, 404, 133309.

14. Kazmi, M. A., Meesaraganda, L. V. P., & Babu, P. S. C. (2023). Durability performance of self-compacting concrete produced using CO2 as an admixture. Materials Today: Proceedings.

A Combined Approach based on Histogram of Oriented Gradients and Convolutional Neural Network to detect Lung Cancer

Ritu Nagila*
Research Scholar
Department of Computer Science & Engineering
IFTM University
Moradabad, Uttar Pradesh
✉ ritu.upadhayay01@gmail.com

Abhishek Kumar Mishra
Associate Professor
Department of Computer Science & Engineering
IFTM University
Moradabad, Uttar Pradesh
✉ abhimishra2@gmail.com

ABSTRACT

On a global scale, lung carcinoma, more often known as lung cancer, ranks as the top cancer fatality. Tackling lung cancer is a highly intricate issue to resolve. Lung cancer patients have heightened susceptibility to SARS-CoVID-19 infection, although early detection significantly enhances the chances of survival. In recent years, medical imaging system researchers have focused heavily on improving computed tomography (CT) for the detection of lung cancer. Consequently, there is a need to swiftly analyse, identify, categorize, and assess CT scans. This research proposes a technique for identifying and categorizing lung nodules (or lesions) through the implementation of a multi-strategy system. The SegNet architecture is employed for the purpose of segmenting CT scans, while the detection of lung cancer from CT images is accomplished by utilizing combined characteristics of HOG (Histogram of Oriented Gradients) and CNN (Convolutional Neural Network). In this study 2D CNN comprises three distinct CNNs that employ varying layers, kernels, and pooling approaches. Using a 2D Deep Ensemble CNN with HOG yielded a commendable outcome, with a combined accuracy of 96.5%, surpassing the accuracy of the baseline approach.

KEYWORDS : *Lung cancer detection, Image processing, CNN, HOG, SegNet architecture, Gaussian filter.*

INTRODUCTION

The World Health Organization reports that cancer ranks as the top cause of mortality worldwide, resulting in about ten million fatalities in 2022. In 2021, lung cancer ranked as the second leading cause of mortality, resulting in 2.21 million new cases and 1.80 million deaths [1]. As to the recent data by the World Health Organization, Lung Cancer has ascended from the ninth to the sixth position in the ranking of diseases with the highest mortality rates. Lung cancer is characterized by the uncontrolled proliferation of aberrant cells, known as nodules, in the lungs. The anomalous cells proliferate and give rise to neoplasms, impeding the normal functioning of the lungs. The primary catalyst for these modifications is the inhalation of noxious compounds or substances. Based on the cells from which the disease develops, small cell lung cancer (SCLC) and non-small cell lung cancer (NSCLC) are the two primary classifications for lung cancer. These varieties are handled differently and have their own unique traits. Nodules in the lungs are little growths of tissue that can be malignant or benign, additionally known as benign or cancerous nodules in the lungs. Tissues that are considered benign usually have a low risk of cancer and grow slowly, whereas tumors that are considered malignant grow quickly and can metastasize (spread to other bodies). An especially formidable challenge is the problem of lung cancer. Timely identification of lung cancer is crucial in order to minimize fatalities and significantly enhance the chances of survival. Radiologists employ non-invasive diagnostic imaging techniques like computed tomography (CT) scans to get detailed pictures of the insides of the body, including the organs, soft tissues, blood arteries, and bones. A CT scan is the imaging modality of choice for screening for lung cancer. Diagnosing lung cancer relies heavily on the capacity to detect and understand lung nodules. Radiologists confront a significant challenge in detecting small lung nodules on CT scans, which contain millions of pulmonary voxels. The patient does not receive enough time to prepare for the diagnosis since the nodule, a tiny lesion forming inside the lung, is only around the size of a dime when it is not detected early enough. On top of that, these minute anomalies are undetectable by X-rays; only a CT scan can pick them up. Radiologists still need a lot of training and experience to figure out if the nodules (lesions) are benign or very malignant, even after detection.

In order to tackle this problem, automated techniques have been created, and recent advancements have resulted in accuracy levels that are now comparable to or even higher than human interpretation. Another advantage of automated approaches is that they make radiologists work less subjective and unpredictable. In many areas, including medical imaging, feature extraction, and object classification, deep learning has proven to be the most effective method for learning. This research relies on the Convolutional Neural Network (CNN), a supervised deep learning model, to reliably classify the results as malignant or benign. A concise definition of comprehending deep learning is that it acquires knowledge by assimilating patterns from given instances. It operates in a manner similar to the functioning of our brain, acquiring knowledge through the analysis of instances. When it comes to lung cancer classification, several researchers have proposed many deep learning architectures. Using CT scan datasets, this study aimed to assess how well deep learning systems could detect and categorize lung abnormalities. A multi-strategy CT-based approach to the detection and classification of lung nodules (or lesions) of both types (NSCLC and SCLC) is presented in this study. Figure 1 depicts the suggested methodology. The process consists of two components: nodule detection, which involves identifying nodules, and classification, which involves sorting nodules into two groups: benign (not cancerous) and malignant (cancerous). The objective of semantic segmentation tasks, for which SegNet is developed, is to assign a predetermined class to each pixel in an image. Despite SegNet's popularity in image segmentation and other computer vision applications, it might not be the finest option for immediate detection of lung cancer. But it can work in tandem with other systems to analyze lung cancer cases which has not be done before. The SegNet architecture is employed for the segmentation of CT scans in order to identify nodules in the lung. Also, lung cancer can be found on CT scans by combining the properties of HOG (Histogram of Oriented Gradients) and CNN (Convolutional Neural Network).

LITERATURE REVIEW

Recent research has introduced a range of advanced neural network structures for identifying and categorizing lung cancer in CT scans, employing different computational methods.

In 2018, Fatema Tuj Johora et al. [1] came up with a way to use Support Vector Machines (SVM) and Back Propagation Neural Networks (BPNN) together to find lung cancer in CT scans. The suggested method works 96.32% of the time in SVM and 83.10% of the time in BPNN.

In 2021, Sneha Balannolla et al. [2] came up with a way to divide up CT scans that uses the U-Net design. They also tested how well the VGG Net worked on 3D pictures from the LUNA 16 and LIDC-IDRI datasets. Both the U-Net and the VGG-Net results were used in the final findings.

Qi Dou et al. [3] developed a method. Multilevel contextual 3-D CNNs reduce lung nodule detection false positives. The suggested method is tested on LUNA 16. This paper proposes a multi-layered 3D ConvNet with Multi-level Contextual. The 3D convolutional layer scans the input image to collect complicated information. A 3D max-pooling layer selects the maximum value in each local region to reduce 3D feature dimensionality and account for local translation invariance. Densely interconnected neurons in the fully connected layer improve feature representation. Four false positives yield 87% sensitivity.

A method for classifying lung tumors as benign or malignant was devised by Haritha Sathyan and colleagues [4] using AlexNet and transfer learning algorithms. The researchers used CT scans of the lungs that were made available to the public via the LIDC-IDRI database. Nodules larger than 3 mm, non-nodules, and nodules less than 3 mm are the three types of lung nodule images used in this investigation. There is minimal chance of false positives and a 98 percent accuracy rate demonstrated by this procedure.

In 2017, K. Dimililer et al. [5] developed an image processing method to detect lung cancer in photographs. As a result, the initial survival rates for lung cancer increased by 14% to 49%.

In their study, P. B. Sangamithraa et al. [6] devised an algorithm for image segmentation. The characteristics of the images were retrieved using the GLCM method and then classified using the BPNN technique for lung cancer.

Wang, Yang et al. [7] developed real-time lung nodule detection. A deep learning model was used to construct a Lung IILS (intelligent imaging layout system) that accurately categorizes nodules (lesions), identifies and acknowledges lesions, and standardizes CT scan pictures and chest data This complete clinical decision support system uses CT scans to monitor and manage lung nodules in the healthcare system. A complex deep learning model architecture called Recursive Convolutional Neural Network was used. The researchers used a non-connected dataset with 11,205 patient CT scans. With 94% consistency, the IILS is strong. With an AUC of 0.90 percent, the IILS distinguishes benign pulmonary lesions from malignant nodules. It detects benign lung nodules with 76.5 percent sensitivity and 89.1 percent specificity. A random sample of 327 cases from the control group was chosen to evaluate the adaptive approach. These instances were selected from those without lung nodules in their clinical reports. After retesting, 318 nodules were absent in 153 patients, 46.8% of the total. Even though Chinese clinicians read differently from the LUNA, LIDC/IDRI datasets, the IILS provides a reliable and exact system for recognizing, categorizing, and organizing CT images of lung lesions to help diagnose the Chinese population.

Using CT scan images, Fang Zhou et al. [8] created a neural network approach to reliably identify lung cancer. There were two parts to the assignment: The first module involved classifying suspicious lesions (nodules) as benign or malignant using a 3D convolutional neural network (CNN) model. Through the use of a leaky noisy model, the second module ascertains the probability of malignancy for every detected nodule. Both units made use of an altered U-net layout. A dataset acquired at the Data Science Bowl competition in 2017 was used by the researchers. Classification accuracy was 81.42% on the test set and 84.96% on the training set. Due to the omission of the nodule development rate, the proposed work is incorrect.

METHODOLOGY

In order to improve the input image's contrast, the suggested solution employs a pre-processing technique. The input image is first converted to grayscale. In order to improve the images, we used the Gaussian filter to boost the contrast. Gaussian filters are ideal for discriminating and constructive representation because their frequency and adaptability characteristics are quite similar to the human visual system [9].

The division process is vital in the area of image processing. The best practice is to divide improved photos into multiple sub-segments. By separating the image into its component parts, we may more accurately portray it. The reasons to partition items might range from making them easier to identify to creating clear borders between different binary systems. Division of a picture into separate areas or objects using pixel clusters, specific surfaces, objects, or natural features is called image segmentation. We generally use a threshold-based methodology in our approach. Feature extraction, which is based on pixel comparisons, is covered in this research. The first step in collecting CT images is to access the public-access database maintained by the LIDC (The Lung Image Database Consortium). Here is the recommended methodology, as seen in Figure 1.

Image Acquisition

To begin processing images, the first step is to acquire them. This stage is alternatively referred to as preparation in the field of image processing. The process entails extracting the image from a typically hardware-based origin. Various techniques are employed to capture medical images, including tactile imaging, computed tomography (CT), magnetic resonance imaging (MRI), positron emission tomography (PET), and others. Usually, a CT scan is the best way to screen for lung cancer. In this study we are using CT-scan images of chest for lung cancer detection from LIDC database which is widely accessible to the public for research motives. Sample images from LIDC dataset are shown in Figure-2. We are taking 80% of the data (i.e. 814 CT-images) for training and 10% (i.e. 101 CT-images) of the data for validating and remaining 10% of the data (i.e. 101 CT-images) for testing.

Image Enhancement

Digital images can be improved for display or analytical purposes through the process of image augmentation. For instance, one can eliminate noise, enhance sharpness, or increase brightness in a picture, so facilitating the identification of crucial characteristics. There are two basic groups of images enhancing strategies: Spatial Domain Method and Frequency Domain Process [10].

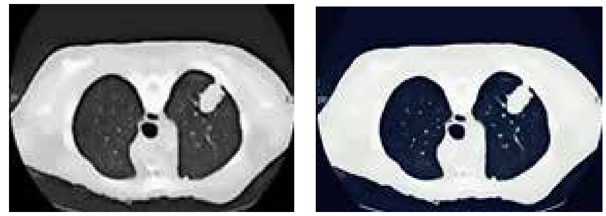
1) Spatial domain techniques refer to methods that directly manipulate individual pixels.

2) Frequency domain approaches involve manipulating the Fourier transform of an image.

Figure-1 samples of the LIDC original CT slices

There are a lot of ways to increase the quality of CT and MRI images, and one of them is by using the Gaussian filter. We used the following Gaussian filter methods when we were improving the images.

Gaussian Filter: In order to blur particular regions of a picture and reduce noise—which is defined as components with a high frequency—a Gaussian Filter—a kind of low pass filter—is used. Each pixel in the region of interest is processed through an odd-sized symmetric kernel [9], which is the matrix equivalent in digital image processing, to apply the filter and achieve the desired result. Figure 3 shows the transformation of original image taken from database to the enhanced image by using Gaussian filter.



Original Image Enhanced image

Figure 2: Image Enhancement by Gaussian filter

To begin reducing noise in an image using the Gaussian Filter, one must first decide on the size of the Kernel/ Matrix. Odd numbers are usually used to represent the sizes, in order to conduct the last computations on the central pixel. The Kernels have an equal number of rows and columns, which is known as symmetry. One way to explain the calculation of the values within the kernel using the Gaussian function is as follows:

$$G(x,y) = \frac{1}{2\pi\sigma^2}e^{-\frac{x^2+y^2}{2\sigma^2}} \tag{1}$$

Where,

x → Value of the X-coordinate

y → Value of the Y-coordinate

π → Value of Mathematical Constant PI (value = 3.13)

σ → Standard Deviation

3.2 Image Segmentation

Segmenting an image into its component pixels and representing each portion with a mask or a tagged image is known as image segmentation. Through the process of breaking a picture into segments, it is possible to process only the [11] segments of the image that are of significant importance, rather than processing the complete image. For this research, we employed the SegNet Architecture [12] for image segmentation.

SegNet Architecture

SegNet is a model that does semantic segmentation. Primarily, trainable segmentation architectures include pixel-wise classification layers, appropriate decoder networks, and encoder networks [13]. The encoder network's design is topologically indistinguishable from the 13 convolutional layers. Figure 4 shows a SegNet architecture for image segmentation.

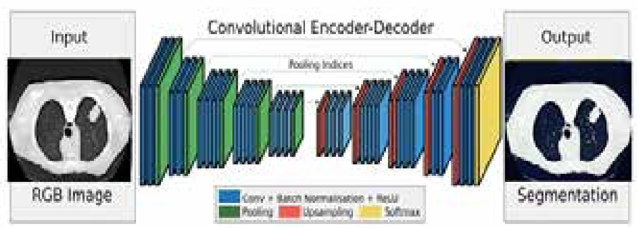


Figure 3. SegNet Architecture

In order to maintain the same resolution as the input image, SegNet utilizes Upsampling in its decoder. This process involves storing certain information. Gaining and storing boundary information inside the encoder feature maps is a must before sub-sampling. To optimize space usage, SegNet selectively maintains just the indices of the maximum feature values in each pooling window for each encoder map. A window size of 2x2 requires just 2 bits, resulting in a small decrease in accuracy, but it is a worthwhile compromise.

Feature Extraction

In this research we are using Gabor filter for feature extraction. It is well-suited for feature extraction in medical imaging activities due to their effectiveness in collecting fluctuations and fine features in CT-scan images. The first step in extracting features with a Gabor filter is to apply a two-dimensional Gabor filter to each image separately. The procedure is dictated by Gabor's uncertainty principle, which asserts that the result of multiplying frequency resolutions with time must be more than a constant. Better orientation and frequency selection is made possible by the principle. The Gabor filter function, as defined by the following equation, has been implemented on every image:

$$G_{p,q,f,\theta}(x,y) = \exp\left(-\frac{(x-p)^2}{\alpha^2} - \frac{(y-q)^2}{\beta^2}\right)$$

$$\exp[j2\pi f((x-p)\cos\theta + (y-q)\sin\theta)] \tag{2}$$

Classification

Image classification refers to the systematic categorization and labeling of clusters of pixels or vectors in an image, guided by predetermined criteria. The classification legislation can be formulated by utilizing one or many spectral or textural attributes. After extracting features we have classified that images into category of benign (non-cancerous) or malignant (cancerous).

To achieve this, we have used following methods and algorithm:

Convolutional Neural Network (CNN)

One common type of neural network used for deep learning, a Convolutional Neural Network (CNN) is most commonly used in computer vision scenarios. A subfield of AI known as "computer vision" allows computers to process visual information such as images.

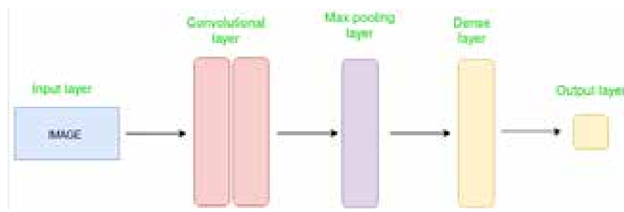


Figure 4. Simple CNN architecture

Figure 6 shows a simple architecture of CNN. Several layers make up a convolutional neural network (CNN), including the input layer, the pooling layer, the convolutional layer, and the fully linked layers. Utilizing filters, the Convolutional layer extracts feature from the input image, while the Pooling layer decreases image size to reduce computational requirements, and the fully connected layer produces the final prediction. The network optimizes its filters using back propagation and gradient descent to achieve maximum effectiveness.

Histogram of Oriented Gradients (HOG)

In computer vision and image processing, the Histogram of Oriented Gradients (HOG) is used as a feature descriptor for object recognition. This technique quantifies the frequency of gradient orientation within certain regions of an image. After dividing the image into smaller cells, the HOG method determines the orientation and amplitude of the gradients in each cell and then compiles all of the gradient data into a histogram of oriented gradients. These histograms provide a description of the visual attributes and are capable of detecting objects inside an image.

Steps to calculate HOG Features

1. The first step in calculating HOG features is to obtain the input image. Create a new image with

the dimensions 128 pixels in height and 64 pixels in width.

2. Then determine the image's gradient. A combination of the image's magnitude and angle yields the gradient. Taking into account a 3x3 pixel block, initially, for every pixel, Gx and Gy are computed. The formulas below are used to determine Gx and Gy for each pixel value.

$$G_x(r,c) = I(r,c+1) - I(r,c-1) \quad G_y(r,c) = I(r-1,c) - I(r+1,c) \tag{3}$$

where r is the row and c is the column.

3. Following the computation of Gx and magnitude, the formulae provided below are used to determine the angle of each pixel.

$$Magnitude(\mu) = \sqrt{G_x^2 + G_y^2} \quad Angle(\theta) = |\tan^{-1}(G_y/G_x)| \tag{4}$$

Combining CNN and HOG

The 2D CNN algorithm, a type of supervised deep learning, is optimized here with HOG for the purpose of identifying lung [14] nodules. This section provides a comprehensive explanation of each step involved in the Deep Ensemble 2D CNN model with HOG, which aims to achieve optimal results and contribute to the development of a CAD system for Lung Nodule Detection. The purpose of this Ensemble Convolutional Neural Network (CNN) with HOG is to extract the accurate properties that are crucial for distinguishing a genuine nodule from other potential nodules. Ultimately, we have computed Accuracy, Precision, and Recall utilizing the formula as:

$$\text{Accuracy} = \frac{TPV + TNV}{TPV + FPV + TNV + FNV} \tag{5}$$

$$\text{Precision} = \frac{\text{TPV}}{\text{TPV} + \text{FPV}} \tag{6}$$

$$\text{Recall} = \frac{\text{TPV}}{\text{TPV} + \text{FNV}} \tag{7}$$

The above equations define the variables TPV as the true positive value, TVN as the true negative value, FPV as the false positive value, and FNV as the false negative value.

The operational procedure of the model is explained in a sequential manner.

Retrieve the dataset from LIDC

2. Data pre-processing involves several steps to ensure the data is balanced, plotted, augmented, and features are extracted.
3. Creating two sets of data: one for training and one for testing.
4. Making use of a HOG-enabled Deep 2D Convolutional Neural Network for both testing and training.
5. Merge the forecast of Deep 2D CNN and HOG.
6. Lung cancer prognosis in absolute terms

Dataset

LIDC

The LIDC dataset contains lesion annotations from four experienced thoracic radiologists. LIDC-IDRI contains 1,018 low-dose lung CTs from 1010 lung patients. The pivotal stage in any research endeavour is the acquisition of data, as procuring accurate data facilitates the attainment of superior outcomes. To begin, the initial task is arranging the vast collection of CT Scan images. The research was done using a data collection of CT scan pictures obtained from the LIDC data set. Collecting high-quality data is crucial for facilitating machine comprehension. All CT Scan images exhibit uniform quality in conveying diagnostic information to any physician. The images in the LIDC Data collection were stored in the formats of (.mhd) and (.raw) files. The .mhd files stored the metadata, whereas the raw files included the multidimensional image data. We utilized the SimpleITK python module to preprocess all of these images and extract data from .mhd files.

Platform

To efficiently analyze a substantial volume of CT-image data, Hadoop platform is capable of managing storage, retrieval, processing, and analysis of such data. The highly distributed file system (HDFS) offers a scalable option for storing CT images. Large datasets can be stored across numerous nodes in a Hadoop cluster using HDFS, thanks to its distributed nature. This ensures fault tolerance and high availability. Preprocessing operations on CT scans of lung cancer are accomplished using Hadoop's MapReduce. To extract features from

CT scans of lung cancer using pre-trained convolutional neural networks (CNNs), Hadoop are coupled with deep learning frameworks of TensorFlow. Machine learning models for lung cancer detection are trained using Spark's MLlib package in Hadoop.

Experimental results and analysis

Once the data has been pre-processed in the appropriate format, the next crucial step is to evaluate the data using our Deep Ensemble 2D CNN Architecture with HOG. Accordingly, the entire dataset was divided into training and validation data. Both data segments contain files for lung nodules, some of which are cancerous and some are non-cancerous. This allows the CNN Model to be exposed to both types of data during training.

This portion employs the Deep Ensemble 2D CNN architecture and allocates 10% of the data for validation, allowing 90% of the data to be used for training. Simultaneously training and testing models is beneficial. For this model, we iterate the dataset 70 times by setting the number of epochs to 70 in the fit generator.

Prediction 1- CNN1+HOG

This section provides an analysis of the performance of (CNN1+HOG) on the given dataset. In the initial CNN1+HOG model, we first executed it on the training and validation datasets. Following the outcomes, the test data was provided to the model in order to forecast the outcome of the CNN1+HOG. The initial iterative model of CNN1+HOG achieves an accuracy of 96.5%, which is considered excellent based on AUC accuracy values. As previously stated, the model was constructed using 90 epochs. The validation split for each epoch divides 80% of the data into the training set and 10% of the data into the validation set. The training progress and epochs indicate that the classification accuracy is improving. Simultaneously, the model's loss diminishes dramatically with each iteration.

Prediction 2- CNN2+HOG

Following the previous section's description of (CNN1+HOG)'s performance review, this section explains how (CNN2+HOG) performed on the test data. We used training and validation data to run the second CNN+HOG model. We fed this model the test data after we got the results so it could forecast the (CNN+HOG)'s output. The following are some of the positive outcomes produced by the second CNN+HOG model. There is a precision of 0.93 in the outcome as well. From the first iteration to the last, the accuracy is steadily growing.

Prediction 3- CNN3+HOG

In the sections that follow the description of (CNN2+HOG)'s performance review, we detail how CNN3+HOG performed on the testing data. Using both training and validation data, we initially put the third CNN+HOG model through its paces.

We fed this model test data after the results so it could predict the (CNN+HOG)'s performance. Consequently, we have included some encouraging results from the CNN3+HOG third model.

The accuracy and loss during training for all CNN+HOG model are explained in Table 1.

Table 1. Results of CNN1+HOG, CNN2+HOG, CNN3+HOG

	CNN1 + HOG	CNN2 + HOG	CNN3 + HOG
Training accuracy	0.9546	0.9474	0.9389
Testing accuracy	0.9545	0.9473	0.9367
Value loss	0.1534	0.175	0.1920

Comparison

In this part, we compare and contrast how well each CNN+HOG performed on the provided data. First, we trained and validated the CNN model using the two datasets. We performed 90 iterations to represent complete pass through the training dataset during the training of a model. In order to forecast the CNN's output, the model was fed test data after the outcome. According on the AUC accuracy values, the initial iterative CNN model achieves a 96.5% accuracy, which is considered excellent. The results are explained in Figure 5.

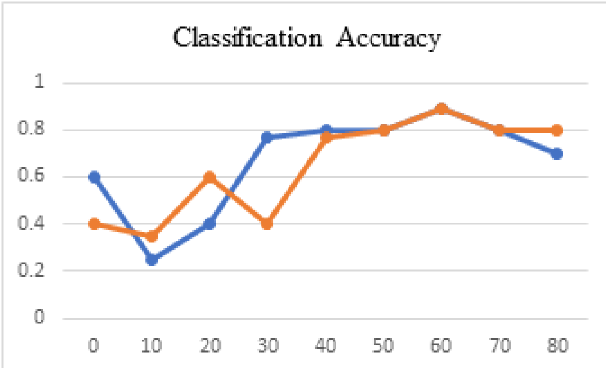


Figure 5. Accuracy curve of CNN3+HOG

Combine results of all optimised CNN (CNN1+HOG, CNN2+HOG, CNN3+HOG)

When the three predictions from the Optimized Convolutional Neural Networks (CNNs) are combined with the HOG, which were specifically devised for addressing the Lung Nodule problem. The accuracy curve demonstrates disparities in the values of TP, TN, FP, and FN, indicating that the decision to combine all three CNN models was a commendable one with regard to improving precision and reducing the frequency of False Positives.

With its three distinct (CNN+HOG) s, our model is able to reach an accuracy level of 90% or higher. Our first (CNN1+HOG) achieved 95.57% accuracy, our second CNN2+HOG achieved 95.44% accuracy, and our third CNN3+HOG achieved 95.14% accuracy. Table 2 shows the final outcomes of the model.

Table 2. Combine results of all CNNs and HOG.

Accuracy	96.5%
Precision	0.95%
Recall	0.82%

A Comparison table is shown in table 3. This summary provides a succinct overview of the performance, interpretability, computational complexity status of each method, allowing readers to quickly grasp the comparative strengths and weaknesses.

In this table:

Author: Specifies the author for each reviewed study.

Dataset: Indicates the type of imaging data used in the study (e.g., lung CT, chest X-rays, PET/CT scans).

Architecture: Describes the algorithm, architecture or methodology employed in the study, including any novel techniques or approaches utilized.

Evaluation Metrics: Presents the performance metrics reported in each study, such as accuracy, precision, and recall.

Interpretability: Assesses the interpretability of the model's predictions, indicating the clarity with which insights into the decision-making process are provided.

Computational Complexity: Evaluates the computational complexity of the method, considering factors such as model size, training time, and resource requirements.

Table 3. Comparison table

Author	Dataset	Architecture	Evaluation Metrics (Accuracy, Precision, Recall)	Interpreta-bility	Computational Complexity
Proposed Method	Lung CT Data from NLST dataset	CNN+HOG	Accuracy: 0.96, Precision: 0.95, Recall: 0.82	High	Medium
Fatema Tuj Johora et al., [1]	IMBA Home (Via-LCAP public access) image database consortium (LIDC) dataset	SVM and BPNN	SVM Accuracy: 0.83, Precision: 0.96, Recall: 0.96 BPNN Accuracy: 0.96, Precision: 0.92, Recall: 0.65	Low	High

Sneha Balannolla et al., [2]	LUNA 16 and LIDC - IDRI	U-Net and VGG-Net	Accuracy: 0.97, Precision: 0.96, Recall: 0.98	Low	High
Zhao et al., [3]	LIDC dataset	CNN with LeNet and AlexNet	Accuracy: 0.82, Precision: 0.87, Recall: 0.86	Medium	High
Sathyan H et al., [4]	LIDC-IDRI dataset	CNN with AlexNet	Accuracy: 0.98, Precision: 0.87, Recall: 0.86	Medium	High
Yang Wang et al., [7]	Institutional review board of the University Medical Center.	IILS based on deep learning.	Accuracy: 0.90, Precision: 0.94, Recall: 0.84	Low	High

CONCLUSION

Each year, a significant number of fatalities are attributed to cancer, a trend that is steadily rising. Enormous sums of money have been allocated to cancer research. It remains an unresolved enigma that requires resolution. Ongoing cancer research persists indefinitely as a definitive outcome has yet to be achieved. There are no established criteria utilized for the identification and anticipation of cancer. The field of cancer research remains an unresolved matter that requires further attention. The most recent study conducted on the current data set will provide opportunities for further investigation by presenting the newest statistics and insights into our accomplishments thus far in the field of cancer detection and prediction. Gaining knowledge on the most recent causes or indicators of cancer would be beneficial.

The researchers presented numerous prior studies in the related work section to identify lung cancer. The researchers faced challenges in terms of low accuracy, inadequate methods, and an inefficient dataset. The present study was designed to address the limitation of the previous study by employing the Deep 2D CNN methodology. The proposed study utilizes three CNN models, namely CNN1, CNN2, and CNN3 with HOG. Subsequently, the ensemble 2D approach of deep learning amalgamates all three of these deep learning methods. The ensemble deep learning method achieves a remarkable accuracy of 96.5%, surpassing the highest known accuracy of any previous deep learning algorithm in identifying lung cancer. This paper presents cutting-edge findings of an ensemble learning methodology for accurately detecting lung cancer from a collection of images. A future advancement could be a system that detects lung cancer cases accurately by combining a big and efficient dataset with numerous algorithms in ensemble learning.

REFERENCES

1. Fatema Tuj Johora, Mehdi Hassan Jony, Parvin Khatun, “A New Strategy to Detect Lung Cancer on CT Images”, International Research Journal of Engineering and Technology (IRJET), Volume: 05 Issue: 12 | Dec 2018, e-ISSN: 2395-0056, p-ISSN: 2395-0072.

2. Sneha Balannolla, Dr. A. Kousar Nikhath, Dr. Sagar Yeruva, “Detection and Classification of Lung Carcinoma using CT scans”, Journal of Physics: Conference Series, doi:10.1088/1742-6596/2286/1/012011, IOP Publishing, ICSTSD-2021.

3. Zhao , S. Qi, L. Liu , Y. Teng, J. Li, & W. Qian,“Agile convolutional neural network for pulmonary nodule classification using CT images” Int. J. Comput. Assist. Radiol. Surg., vol. 13, no. 4, pp. 585–595, February. 2018

4. Sathyan H, Panicker J.V: “Lung Nodule Classification Using Deep Convolution Using Deep ConvNets on CT Images” (October 2018), ICCNT 2018

5. K. Dimililer, Y. Kirsal-Ever, and B. Ugur, “Tumor Detection on CT Lung Images using Image Enhancement,” The Online Journal of Science and Technology, vol. 7, Jan. 2017, pp. 133-138.

6. P. B. Sangamithraa, and S. Govindaraju, “Lung tumour detection and classification using EK-Mean clustering,” Proc. International Conference on Wireless Communications, Signal Processing and

NETWORKING (WiSPNET 16), IEEE, Mar. 2016, pp. 2201-2206, doi:10.1109/WiSPNET.2016.7566533.

7. Wang, F.-R.; Lu, X.-F.; Y.; Yan, Zheng, G.-M.; Zhang, X..; Zhou, Wang, C K.-F.; Zhang, Y.- W.; Li, H.; Zhao, Q.; et al. IILS: Intelligent imaging layout system for automatic imaging report standardization and intra-interdisciplinary clinical workflow optimization. EBioMedicine 2019, 44, 162–181.

8. Fang Zhou.; Liao, Liang, M.; Li, X.-L.; Song, Z.; Hu, S.:" Evaluate the Malignancy of Pulmonary Nodules Using the 3-D Deep Leaky Noisy-or Network". IEEE Trans. Neural Netw. Learn. Syst. 2019, 30, 3484–3494

9. S. Avinash, K. Manjunath and S. Kumar, "An improved image processing analysis for the detection of lung cancer using Gabor filters and watershed segmentation technique", 2016 International Conference on Inventive Computation Technologies (ICICT), 2016.

10. H. Rutika r, "Automated detection and diagnosis from lungs CT scan images", International Journal of Emerging Technologies and Innovative Research (www.jetir.org — UGC and issn Approved), ISSN:2349-5162, vol. 2, no. 3, pp. pp785-787, 2015.

11. M. Firmino, G. Angelo, H. Morais, M. Dantas and R. Valentim, "Computer-aided detection (CADe) and diagnosis (CADx) system for lung cancer with likelihood of malignancy", BioMedical Engineering OnLine, vol. 15, no. 1, 2016.

12. Xiaodong Chena, Qiongyu Duana, Rong Wua and Zehui Yang, "Segmentation of lung computed tomography images based on SegNet in the diagnosis of lung cancer", JOURNAL OF RADIATION RESEARCH AND APPLIED SCIENCES 2021, VOL. 14, NO. 1, 396–403 https://doi.org/10.1080/16878507.2021.1981753.

13. E. Chamseddine, L. Tlig, M. Sayadi and M. Bouchouicha, "SegNet Architecture for Dermoscopic Image Segmentation," 2022 IEEE Information Technologies & Smart Industrial Systems (ITSIS), Paris, France, 2022, pp. 1-6, doi: 10.1109/ITSIS56166.2022.10118404.

14. Asghar Ali Shah, Hafz Abid Mahmood Malik, Abdul Hafeez Muhammad, Abdullah Alourani & Zaeem Arif Butt, "Deep learning ensemble 2D CNN approach towards the detection of lung cancer", Scientifc Reports | (2023) 13:2987 | https://doi.org/10.1038/s41598-023-29656-z

Health Insurance and Cross-Sell Prediction Using Python

Shaheen Jabir Khan
Lecturer, Department of Huminities
VPM's Polytechnic
Thane, Maharashtra
✉ mat21sj.khan@pg.ictmumbai.edu.in

ABSTRACT

In this project, we built several models that predict whether the customer is interested in taking vehicle insurance based on prior health insurance of the customer. Nowadays the use of automobiles is increasing rapidly. this increase has made insurance company to make it as a business target for an insurance company. The customers interested in taking vehicle insurance are predicted based on the information of existing health insurance of the customer. If the prediction is made based on the information of existing customers data then it can give profit to the insurance company. This study aims to maximize insurance company's profit. The program algorithm uses logistic regression, Decision tree, Random forest,Gradient Boosting(GB), and XGB According to the result of our project Driving License and Previously Insured are two main features in predicting the model,and by comparing one model with others we get random forest as the best-fitted model with 86% overall accuracy with 96.71%of specificity. Therefore, customers with health insurance could induce a positive relation to vehicle insurance.

***KEYWORDS** : Predictive modeling, Insurance interest prediction, Health insurance, Vehicle insurance, Data analysis, Classification, Machine learning, Feature engineering, Model evaluation.*

INTRODUCTION

In today's rapidly evolving world, driven by data, the insurance industry is continually adapting its marketing strategies to better connect with customers. It's crucial for insurance companies to understand customer preferences and behaviors, particularly in predicting their interest in different insurance products. This project aims to tackle this challenge head-on by delving into the realm of predictive modeling.

Specifically, our focus is on predicting whether customers who already have health insurance would also be interested in purchasing vehicle insurance. We'll analyze various factors such as age, gender, and past insurance history to make these predictions. By carefully examining these details and using advanced analytical techniques, our goal is to develop models that can accurately forecast customer interest.

The ultimate objective is to provide insurance companies with valuable insights to help them tailor their marketing efforts more effectively and ultimately boost sales. This project has been prompted by a need within the insurance sector looking to predict whether customers who already have health insurance would also be interested in purchasing vehicle insurance. By leveraging the power of predictive modeling, we aim to empower insurance companies to make informed decisions and strengthen their relationships with customers.

Significance

The significance of this study lies in its potential to revolutionize the insurance industry's approach to customer targeting and marketing. By accurately predicting customer interest in vehicle insurance, insurance companies can tailor their marketing efforts more effectively, thereby maximizing revenue and enhancing customer satisfaction.

OBJECTIVE

The primary objective of this project is to leverage advanced predictive modeling techniques to accurately forecast customer interest in vehicle insurance among those who already possess health insurance. Specifically, our aims are:

1. To analyze a diverse range of customer data,

including demographic information and insurance history, to identify key factors influencing interest in vehicle insurance.

2. To develop predictive models using sophisticated machine learning algorithms that can effectively predict customer interest based on the identified factors.
3. To evaluate the performance of the predictive models using robust metrics such as accuracy, precision, and recall, ensuring their reliability and effectiveness.
4. To provide actionable insights to insurance companies, enabling them to optimize their marketing strategies and target potential customers more efficiently.

Through achieving these objectives, we aim to contribute to the enhancement of data-driven decision-making in the insurance industry and facilitate the development of more tailored and effective marketing approaches.

Business Goal

Building a model to predict whether the customer is interested in taking vehicle insurance.

DATA DESCRIPTION

1. id - Unique id for each Customer
2. Gender - Gender of Customer(a) Male (b) Female
3. Age - Age of the customer
4. Driving License (a) 0 - Customer does not have Driving License (b) 1 - Customer has

Driving License

5. Region Code - Unique code for the region of the customer
6. Previously Insured (a) 0 - Customer doesn't have Vehicle Insurance (b) 1 - Customer has

Vehicle Insurance

7. Vehicle Age - Age of the Vehicle
8. Vehicle Damage (a) 0 - Customer didn't get his/her vehicle damaged in the past. (b) 1 -

The customer got his/her vehicle damaged in the past.

9. Annual Premium - The amount customer needs to pay as premium in the year.
10. Policy Sales Channel - Anonymized Code for the channel of outreaching to the customer i.e. Different Agents, Over Mail, Over Phone, In Person, etc.
11. Vintage - Number of Days, Customer has been associated with the company.
12. Response (a) 0 - Customer is not interested (b) 1 - Customer is interested.

Feature Engineering

Feature engineering was conducted to transform the raw dataset into meaningful features suitable for predictive modeling. This process involved analyzing the data and extracting relevant information to enhance the performance of the models.

Handling Class Imbalance

Class imbalance, where a large majority of individuals showed no interest in vehicle insurance, posed a significant challenge. To address this issue, oversampling and under sampling techniques were employed to balance the dataset. By adjusting the class distribution, we aimed to prevent bias in the model and ensure effective learning from both classes.

Model Building

Following the balancing of the dataset, predictive models were built using various algorithms, including Logistic Regression, Decision Trees, Random Forest, Gradient Boosting, and XGBoost. These models were trained on the balanced dataset and evaluated using metrics such as training accuracy, test accuracy, precision score, and recall score.

Model Performance

The performance of each model was assessed based on its training and test accuracies, as well as precision and recall scores. Notably, the Random Forest model exhibited the highest test accuracy (88.12%), making it a promising candidate for predicting customer interest in vehicle insurance.

Model	Training Accuracy	Test Accuracy	Precision Score	Recall Score
Logistic Regression	77.01%	76.60%	87.94%	90.63%
Decision Tree	83.11%	82.80%	75.39%	95.49%
Random Forest	86.01%	88.12%	81.22%	98.00%
Gradient Boosting	83.98%	82.99%	74.89%	95.15%
XGBoost	85.90%	82.70%	75.32%	95.30%

CONCLUSION

This project has made significant strides in predictive modeling for the insurance industry. By leveraging advanced analytics, we've successfully predicted customer interest in vehicle insurance among those with existing health insurance.

Our models, based on factors like age, gender, and past insurance history, offer actionable insights for insurers to tailor their marketing strategies and boost customer engagement.

Moving forward, these findings pave the way for further innovation in data-driven decision-making, empowering insurers to make informed choices, strengthen customer relationships, and thrive in a rapidly evolving market landscape.

REFERENCES

1. https://statinfer.com/material/

2. https://gutentagworld.wordpress.com/2020/12/13/health-insurance-cross-sell-prediction

3. https://www.policybazaar.com/life-insurance/general-info/articles/things-must-know-before-paying-life-insurance-premium

A Comprehensive Review of Spam Email Detection using Machine Learning Techniques

Vinodini Salvi
✉ vini.salvi14@gmail.com

Sujata Bhairnallykar
✉ sujata@comp.sce.edu.in

Department of Computer Engineering
Saraswati College of Engineering
Kharghar, Navi Mumabi, Maharashtra

ABSTRACT

Because email spam poses a constant danger, robust detection methods are essential. An detailed overview of spam filtering techniques, including client-side, enterprise-level, and standard methods, is given in this document. Machine learning, including supervised, unsupervised, and reinforcement learning, is the topic of discussion. Three well-known algorithms that exhibit promise in supervised settings include Support Vector Machines, Random Forest, and Naïve Bayes. Unsupervised methods such as K-means clustering and artificial neural networks are used to solve word obfuscation problems. Reinforcement learning introduces dynamic flexibility. The paper identifies areas in which further research is needed and suggests deep learning, hybrid algorithms, and feature extraction using real-world data. Clustering techniques, block chain integration, GPU/FPGA use, picture spam detection, multilingual issues, and robust security measures are some of the important future directions to watch.

***KEYWORDS** : Machine learning, Supervised learning, Unsupervised learning, Reinforcement learning, Email spam.*

INTRODUCTION

In today's digital communication landscape, spam emails have become a global problem that affects both individuals and organizations. The amount of unwanted and harmful emails has increased to an alarming degree, posing serious risks to critical information security and personal privacy. Spam clogs inboxes of individuals, frustrating them and sometimes causing them to miss important communications. Larger-scale threats to an organization's finances and reputation include the possibility of phishing scams, malware dissemination, and data breaches through spam. [1, 2]

Spam has more negative effects than just being inconvenient; it can damage communication lines and interfere with crucial business processes. Traditional rule-based and heuristic approaches are becoming less and less effective at recognizing and blocking these unsolicited messages as spam techniques change. Thus, it is essential to create effective and flexible spam detection techniques. [3]

This paper looks at the challenges posed by spam emails, tries to provide a comprehensive overview of the state of spam detection today, and emphasizes the critical role that machine learning plays in overcoming this pervasive issue. By examining the current status of spam detection approaches, we lay the groundwork for a thorough investigation of machine learning techniques and their potential to enhance the accuracy and efficacy of spam filtering systems. Through this inquiry, we intend to gather information that will guide the development of more dependable and adaptable spam detection systems in the future.

Table. 1 Overview of Research Surveys on Email Spam Detection Approaches and Techniques

Overview	Approaches and Techniques	Inputs	Outputs	References
Survey on email spam detection using a supervised approach with feature selection. Knowledge discovery process discussed. Various models and techniques for spam detection. N-Gram-based features.	Supervised learning, N-Gram, feature selection	Email content, N-Gram features	Spam detection, knowledge discovery	[10]
Survey on intelligent spam email detection. Discusses security risks, machine learning, and non-machine learning techniques. Emphasis on supervised learning.	Supervised learning, Multi- algorithm frameworks	Email content, metadata	Spam detection and filtering	[11]
List of learning-based email spam filtering approaches. Addresses economic and ethical issues. Highlights Naïve Bayes as a prominent classifier for spam filtering.	Learning-based filtering, Naïve Bayes, various classification techniques	Email components, features	Effective spam filtering	[4, 12]
Review of current email spam filtering approaches. Summarizes efficiency and issues. Emphasizes Naïve Bayes and SVM for filtering.	Naïve Bayes, SVM, various filtering mechanisms	Email content, multimedia data	Next-generation spam filtering	[13]
Review of deep learning algorithms for intrusion and spam detection. Evaluates effectiveness on diverse datasets. Deep learning superiority over traditional models.	Deep learning, traditional machine learning, lexicon models	Various cyber datasets divided into categories	Improved performance in intrusion and spam detection	[9]
Review on supervised machine learning strategies for spam emails. Compares Naïve Bayes, SVM, and ID3. Emphasizes the trade-off between timing and precision.	Supervised learning, Naïve Bayes, SVM, ID3	Email components, various features	Balance between accuracy and timeliness	[13]

SPAM MESSAGE FILTERING TECHNIQUES

Spam in the form of unsolicited mass emails from unknown senders is a common problem. The phrase, which originated from a Monty Python joke, became well-known in 1978 to refer to unsolicited emails, and it really took off in the middle of the 1990s. Email spam is well-known outside of academic circles because of tricks like the "development expense trick." In this scam, victims get emails offering prizes in exchange for money up ahead. The goal of the perpetrators is to make more money, and after they get the victim's payment, they either benefit or stop communicating. In the modern era of technology, email spam is still a major problem due to the various strategies used by spammers and dodgers.

Table 2 Overview of Spam Message Filtering Techniques

Technique	Advantages	Disadvantages	Remarks	References
Standard Spam Filtering Method	- Rules-based system	- Limited adaptability to evolving spam techniques	- Effective for known patterns	[14], [15]
	- Artificial intelligence techniques	- May have high false positive rates	- Sequential filtering process	
	- Header information extraction	- Dependency on user-defined parameters	- Incorporates content, header, and backlist filters	

Client Side Spam Filtering	- Customizable rules for individual users	- Relies on user's system and preferences	- Provides user-specific protection	[16], [17], [18]
	- Enhances email communication security	- Limited in preventing server-side threats	- Operates at the client's end	
Enterprise Level Spam Filtering	- Centralized control on server	- Resource-intensive on server side	- Efficient for organizational protection	[19], [20] [13]
	- Classifies emails as spam or ham	- May have delayed updates for new spam tactics	- Utilizes ranking and list-based techniques	
Case-Based Spam Filtering	- Machine learning-based approach	- Requires extensive data for effective learning	- Adaptable to changing spam characteristics	[21]

Finally, training sets and test sets are added to the machine learning technique to determine whether this is an email or not. Self-observation and the classifier's output are the two last factors that determine whether an email is spam or not [21, 22]. This survey study covers three main types of machine learning that can be used for spam filtering. We discuss issues with spam filtration and detection systems and look at a few articles.

MACHINE LEARNING

Machine learning, which enables computer systems to learn and become more functional without the need for explicit programming, is a critical application of artificial intelligence [23]. The creation of automated procedures for accessing and utilizing training data is the main objective of machine learning algorithms. To begin with, labeled data—like instances or actual experiences—is utilized to spot patterns and enhance decision-making in the future by taking into account user feedback. The primary objective is for machine learning models to acquire knowledge autonomously, without human intervention. There are three primary types of machine learning, each with a specific use.

Numerous studies have focused on spam classification, employing a variety of methods to enhance users' opinions regarding the dependability and usefulness of email correspondence. This study provides a concise overview of the most recent machine learning models and approaches for email spam detection, as well as an evaluation of well-known methods like KNN, SVM, random forest, and Naïve Bayes.

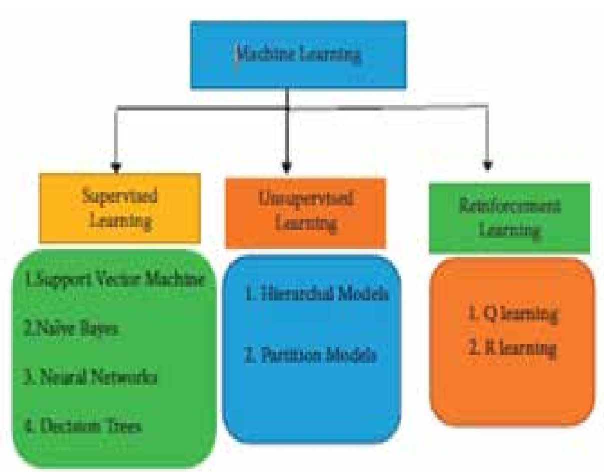


Fig.1. Machine learning types

SUPERVISED MACHINE LEARNING

Algorithms for supervised machine learning require labeled data in order to train [18]. When these models are first trained using labeled training data, they may forecast future events. Following an analysis of the training dataset, the system generates a method for predicting success values. After the algorithm has been correctly trained, it may forecast fresh data based on user training data. By comparing the output to the expected output, the learning process looks for errors in the model to make it better [24]. Numerous problems, such as the popularity of advertisements and the classification of spam, are resolved using supervised learning. Figure 2. shows a diagram of the supervised learning process.

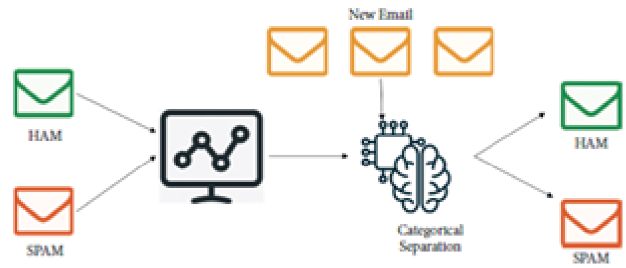


Fig.2. Process of supervised learning

Table.3 Examination of Supervised Methods for Spam Screening

Algorithm	Dataset	Accuracy	Advantages	Limitations	References
Random Forest	Custom collection	95.2%	High accuracy is attained while using numerous trees.	Uses a non-standard dataset, limiting generalizability	[27]
Modified Naïve Bayes	Spam base and spam data	88% (spam base), 83% (spam data)	certain characteristics for quicker processing	Lower accuracy and model intelligence	[30]
Bayes Net, SVM, and NB	Twitter and Facebook dataset	90% (SVM)	combines training and testing using a single dataset	Increased training time due to multiple algorithms and combined dataset	[31]
MLP, Naïve Bayes, Random Forest, Decision Tree	Spam Assassin	99.3% (Random Forest)	employs a list of the most prevalent spam characteristics to enhance detection	A few characteristics taken from a big corpus	[26]
Naïve Bayes, K-nearest Neighbor, SVM, Additive Regression Tree	Real-life dataset	96.69% (SVM)	creates a spam filter using 8,000 actual spam emails as a basis.	Effectiveness limited by evolving spam characteristics	[29]
ID3 Algorithm	Hidden Markov Enron dataset	89%	uses preclassified data to expedite processing	Experiences an 11% loss, indicating suboptimal performance	[28]
CART, C4.5, REP Tree, LAD Tree, NBT	UCI dataset	95.1%	Uses 10-fold cross-validation to improve assessment	Relatively fewer features employed	[25]
SVM	Weibo Social Network Data	99.5%	includes characteristics related to user behavior as well as content	Using statistical analysis and human selection to extract features	[8]

SVM, Deep Learning, Particle Swarm Optimization	Standard datasets from UCI	70% (education data), 93% (SVM)	uses deep learning to extract features	Neural networks need a long training period.	[32]
ELM, SVM Classifier	Enron dataset	94.06% (SVM)	good accuracy in comparison to earlier research	SVM training time is longer than ELM	[5]
SVM, KNN, DT, LR	Health Fitness Data	92.1% (SVM)	makes use of a blockchain with smart contract functionality for increased security	Absence of assessment of suggested model compatibility with IoT framework	[6]
XGBoost, Bagged Model, Generalized Linear Model	Smart Home Dataset	91.8% (Generalized Linear Model)	Applies PCA for enhanced system accuracy	ignores the environmental and climatic aspects of IoT devices	[7]

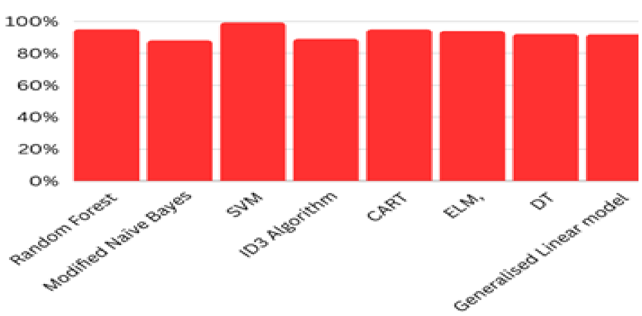


Fig.3. Comparing the Accuracy of Supervised Methods for Spam Filtering

UNSUPERVISED MACHINE LEARNING

Unsupervised machine learning approaches are employed when labeled data is not available [33]. This approach looks into how software could be able to uncover hidden structures by inferring features from unlabeled data [34]. Rather than assessing particular outputs, unsupervised learning entails the computer studying data and drawing conclusions to explain hidden constructs from unlabeled data. This method clusters unlabeled data by using features present in the data. Unsupervised learning can be useful for a variety of applications, including dimensionality reduction, grouping user logs, recommender systems, and buying habit recognition. Refer to the Figure.4 for a summary of the unsupervised learning procedure.

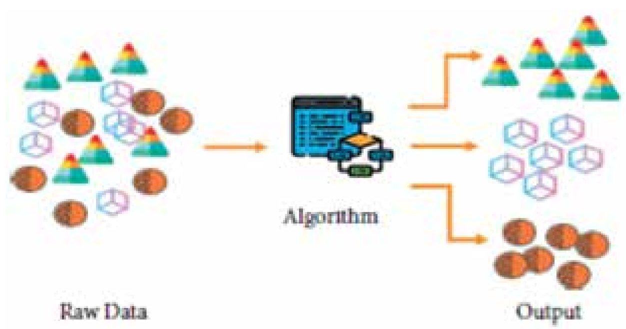


Fig.4. Process of unsupervised learning

Table. 4. Comparative Analysis of Spam Detection Algorithms for unsupervised machine learning

Algorithm Used	Dataset	Accuracy (%)	Benefits	drawbacks	References
Improved Digest and DBSCAN	Spam Assassin	96.7	separates emails into strings of a set length to improve accuracy	Speed depends on the length of strings	[37]
K-means Clustering	UCI Dataset	92.76	Ten-fold cross-validation was used to discretize the data using supervised attribute filters.	Comparing several algorithms requires a significant amount of time.	[35]

Unsupervised Artificial Neural Networks	Enron Email	95	Sturdy enough to obfuscate words in spam without requiring stemming	high rates of false positives and false negatives (around 4% and 11%, respectively))	[38]
Spherical K-means Algorithm	Ling-spam	96.04	uses a variety of spam email contents	Absence of updated spam content and criticism that is relevant	[39]
Equivalence Relations of Strings	Japanese Web Forums	95	scalable and multilingual methodology based on the N-Gram of documents	The value of "n" in the N-Gram determines the results.	[40]
UNIK and SD2	Social Network Sites Data	93	incredibly resilient to rising spam assault levels	Short URLs cannot be handled by the suggested system.	[36]

REINFORCEMENT MACHINE LEARNING

Reinforcement learning is a special sort of machine learning that works by employing incentives that come from the environment. Computers and software use it to determine the best courses of action in specific situations. It entails acting in a way that maximizes benefits in a particular setting [41]. The main difference from supervised learning is the absence of training material with precise labeling. Reinforcement learning focuses on the agent's experience and decision-making to accomplish tasks without requiring a pre-defined dataset, as opposed to proper labels [42]. Figure 14 shows the reinforcement learning process as it applies to an agent interacting with the environment while receiving rewards and state information.

Chiu et al.'s alliance-based spam filter [43] used a genetic algorithm, a machine learning classifier (XCS), and rough set theory to classify and identify the contents of spam emails. They evaluated the model outputs using a variety of criteria and concluded that the spam filter delivered effective spam mail filtering results by combining the benefits of machine learning, genetic algorithms, and rough set theory. This alliance-based spam mail filtering system generated reasonable output indicators [43].

ML'S PERSPECTIVES ON EMAIL SPAM IDENTIFICATION

The Figure.5 illustrates the dissemination of the survey's work on email spam detection. The reliability of classifier outputs is limited because a large number of artificially generated datasets used for model training make it difficult to categorize supervised model data and there aren't enough representative instances. Naïve Bayes, logistic regression, and support vector machines (SVM) are widely used, with SVM generally producing better resultsFuture studies should assess many learning models and feature engineering strategies on various datasets to increase the comprehensiveness of the evaluation. This review looks at the machine learning-based spam filtering techniques now in use, highlighting the need for next-generation filtering techniques that can handle multimodal data and increase accuracy. [9]

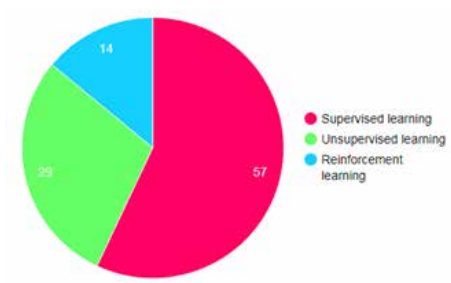


Fig. 5. Ratio of machine learning methods to identify spam emails.

RESEARCH DEFICITS AND UPCOMING PATHS IN SPAM DETECTION

Use of Real-Life Data: Since artificially generated datasets may not perform well in real-world situations, future research should focus on training models using real-life data.

Hybrid Algorithms: Compared to the supervised, unsupervised, and reinforcement learning algorithms used today, hybrid algorithms can improve accuracy and efficiency.

Deep Learning for Feature Extraction: By applying deep learning techniques to feature extraction, spam detection models' feature representation can be enhanced.

Clustering Methods with Relevance Feedback: Spam and ham can be more effectively clustered when clustering methods are combined with dynamic updating for relevance feedback.

Blockchain Integration: Analyze the applications of blockchain concepts and principles to email spam identification.

Using GPUs and FPGAs: Creating spam filters with faster processing and more accurate categorization with the use of GPUs and FPGAs, which allow for real-time processing and low power consumption.

Image Spam Detection: Since skilled spammers are increasingly using images in their spam communications, investigate spam filters that can identify and filter image spam.

Real-Time Spam Classification: To classify spam more effectively, create models that can operate on data that is updated in real-time.

Multilingual Spam Detection: Examine this field of less recent research, multilingual spam detection, employing deep learning algorithms.

Identification of Spammers and Networks: Look on ways to recognize spam networks and individual spammers.

Strong Security Measures: Provide strong solutions to spam filter security issues, perhaps combining blockchain technology and deep learning methodologies.

CHALLENGES OF SPAM DETECTION

Data Volume and New Features: Keeping up with the expanding volume of internet data and the introduction of new features is one of the main problems facing spam detection systems.

Evaluation of Multidimensional Features: When analyzing features from multiple dimensions, including temporal, writing styles, semantic, and statistical factors, spam filters have a challenging task.

Unbalanced Datasets: A lot of models are trained on datasets that are in balance, which reduces the potential for self-learning models to detect spam.

Adversarial Machine Learning Attacks: The efficacy of spam detection models is impacted by adversarial machine learning attacks. Adversaries can provide misleading samples for testing (evasion attack), modify training data (poisoning attack), and use the learning model to get sensitive training data (privacy attack).

The advent of deep fake technology, which makes use of neural network models such as GPT-2, GPT-3, BigGAN, StyleGAN, and CycleGAN, presents a formidable obstacle for spam detection systems. Deep fakes can be used to create, edit, and style films and images, which can spread misleading information.

CONCLUSION

This comprehensive study clarifies the current status of email spam detection while emphasizing the crucial part machine learning plays in resolving the pervasive issue of spam emails. The survey provides information on the advantages and disadvantages of several approaches, ranging from complex machine learning algorithms to traditional rule-based processes. Spam can be identified with excellent accuracy using supervised learning models like Random Forest and Naïve Bayes, whereas unsupervised techniques like K-means clustering and artificial neural networks are resilient to word obfuscation. Reinforcement learning is a dynamic method that offers adaptive responses based on environmental rewards.

REFERENCE

1. Aditya Chaturvedi and Lalit Purohit, "Spam Message Detection: A Review", Int. J. Com. Dig. Sys. 12,

No.1 (Aug-2022), ISSN (2210-142X), https://dx.doi.org/10.12785/ijcds/120135.

2. Naeem Ahmed et.al., "Machine Learning Techniques for Spam Detection in Email and IoT Platforms: Analysis and Research Challenges", Security and Communication Networks, Hindawi, Volume 2022, Article ID 1862888, https://doi.org/10.1155/2022/1862888

3. Lee, H.; Jeong, S.; Cho, S.; Choi, E. Visualization Technology and Deep-Learning for Multilingual Spam Message Detection. Electronics2023,12,582. https://doi.org/10.3390/electronics12030582

4. E. Blanzieri and A. Bryl, "A survey of learning-based tech- niques of email spam filtering," Artificial Intelligence Review, vol. 29, no. 1, pp. 63–92, 2008.

5. S. O. Olatunji, "Extreme Learning machines and Support Vector Machines models for email spam detection," in Proceedings of the 2017 IEEE 30th Canadian Conference on Electrical and Computer Engineering (CCECE), IEEE, Windsor, Canada, April 2017.

6. F. Jamil, H. K. Kahng, S. Kim, and D. H. Kim, "Towards secure fitness framework based on IoT-enabled blockchain network integrated with machine learning algorithms," Sensors, vol. 21, no. 5, p. 1640, 2021.

7. M. H. Arif, J. Li, M. Iqbal, and K. Liu, "Sentiment analysis and spam detection in short informal text using learning classifier systems," Soft Computing, vol. 22, no. 21, pp. 7281–7291, 2018.

8. X. Zheng, X. Zhang, Y. Yu, T. Kechadi, and C. Rong, "ELMbased spammer detection in social networks," 5e Journal of Supercomputing, vol. 72, no. 8, pp. 2991–3005, 2016.

9. M. A. Ferrag, L. Maglaras, S. Moschoyiannis, and H. Janicke, "Deep learning for cyber security intrusion detection: approaches, datasets, and comparative study," Journal of Information Security and Applications, vol. 50, Article ID 102419, 2020

10. N. Kumar and S. Sonowal, "Email spam detection using machine learning algorithms," in Proceedings of the 2020 Second International Conference on Inventive Research in Computing Applications (ICIRCA), pp. 108–113, Coimbatore, India, 2020.

11. A. J. Saleh, A. Karim, B. Shanmugam et al., "An intelligent spam detection model based on artificial immune system," Information, vol. 10, no. 6, p. 209, 2019.

12. E. Blanzieri and A. Bryl, E-mail Spam Filtering with Local SVM Classifiers, University of Trento, Trento, Italy, 2008.

13. T. Vyas, P. Prajapati, and S. Gadhwal, "A survey and eval- uation of supervised machine learning techniques for spam e-mail filtering," in Proceedings of the 2015 IEEE international conference on electrical, computer and communication tech- nologies (ICECCT), IEEE, Tamil Nadu, India, March 2015.

14. W. N. Gansterer, A. G. K. Janecek, and R. Neumayer, "Spam filtering based on latent semantic indexing," in Survey of Text Mining II, pp. 165–183, Springer, New York, NY, USA, 2008.

15. D. Lee, M. J. Lee, and B. J. Kim, "Deviation-based spamfiltering method via stochastic approach," EPL (Europhysics Letters), vol. 121, no. 6, Article ID 68004, 2018.

16. A. K. Jain and B. B. Gupta, "Towards detection of phishing websites on client-side using machine learning based approach," Telecommunication Systems, vol. 68, no. 4, pp. 687–700, 2018.

17. M. F. N. K. Pathan and V. Kamble, "A review various techniques for content based spam filtering," Engineering and Technology, vol. 4, 2018.

18. A. K. Jain and B. B. Gupta, "A novel approach to protect against phishing attacks at client side using auto-updated white-list," EURASIP Journal on Information Security, vol. 2016, no. 1, p. 9, 2016.

19. A. Bhowmick and S. M. Hazarika, "Machine learning for E-mail spam filtering: review, techniques and trends," 2016..

20. M. Bassiouni, M. Ali, and E. A. El-Dahshan, "Ham and spam e-mails classification using machine learning techniques,"Journal of Applied Security Research, vol. 13, no. 3, pp. 315–331, 2018.

21. J. R. M´endez, T. R. Cotos-Yañez, and D. Ruano-Ord´as, "A new semantic-based feature selection method for spam filtering,"Applied Soft Computing, vol. 76, pp. 89–104, 2019.

22. R. Alguliyev and S. Nazirova, "Two approaches on implementation of CBR and CRM technologies to the spam filtering problem," Journal of Information Security, vol. 3, no. 1,

23. E. Alpaydin, Introduction to Machine Learning, MIT Press, Cambridge, UK, 2020.

24. A. Singh, N. (akur, and A. Sharma, "A review of supervised machine learning algorithms," in Proceedings of the 2016 3rd International Conference on Computing for Sustainable Global Development (INDIACom), IEEE, New Delhi, India, March 2016.

25. A. Subasi, S. Alzahrani, A. Aljuhani, and M. Aljedani, "Comparison of decision tree algorithms for spam E-mail filtering," in Proceedings of the 2018 1st International Conference on Computer Applications & Information Security (ICCAIS), IEEE, Riyadh, Saudi Arabia, April 2018.

26. W. Hijawi, H. Faris, J. Alqatawna, A. Z. Ala'M, and I. Aljarah, "Improving email spam detection using content based feature engineering approach," in Proceedings of the Applied Electrical Engineering and Computing Technologies (AEECT), IEEE, IEEE, Aqaba, Jordan, 2017.

27. D. DeBarr and H. Wechsler, "Using social network analysis for spam detection," in Proceedings of the International Conference on Social Computing, Behavioral Modeling, and Prediction, Springer, Ethesda, MD, USA, March 2010.

28. M. Verma and S. Sofat, "Techniques to detect spammers in twitter-a survey," International Journal of Computer Applications, vol. 85, no. 10, 2014

29. M. T. Banday and T. R. Jan, "Effectiveness and limitations of statistical spam filters," 2009, https://arxiv.org/ftp/arxiv/papers/0910/0910.2540.pdf.

30. N. F. Rusland, N. Wahid, S. Kasim, and H. Hafit, "Analysis of Na¨ıve Bayes algorithm for email spam filtering across multiple datasets," in Proceedings of the IOP Conference Series: Materials Science and Engineering, IOP Publishing, Busan, Republicof Korea, 2017.

31. H. Xu, W. Sun, and A. Javaid, "Efficient spam detection across online social networks," in Proceedings of the 2016 IEEE International Conference on Big Data Analysis (ICBDA), IEEE, Hangzhou, China, March 2016

32. M. Zavvar, M. Rezaei, M. Rezaei, and S. Garavand, "Email spam detection using combination of particle swarm optimization and artificial neural network and support vector machine," International Journal of Modern Education and Computer Science, vol. 8, no. 7, pp. 68–74, 2016.

33. M. Diale, T. Celik, and C. Van Der Walt, "Unsupervised feature learning for spam email filtering," Computers & Electrical Engineering, vol. 74, pp. 89–104, 2019.

34. Z. Ghahramani, "Unsupervised learning," in Summer School on Machine Learning Springer, Berlin, Germany, 2003.

35. A. Sharma and V. Rastogi, "Spam filtering using K mean clustering with local feature selection classifier," International Journal of Computer Applications, vol. 108, no. 10, 2014.

36. E. Tan, L. Guo, S. Chen, X. Zhang, and Y. Zhao, "Unik: unsupervised social network spam detection," in Proceedings of the 22nd ACM international conference on Information & Knowledge Management, ACM, San Francisco, CA, USA, October 2013.

37. A. Ahmed, "Improved spam detection using DBSCAN and advanced digest algorithm," International Journal of Computer Applications, vol. 69, 2013.

38. Y. Cabrera-Le´on, P. G. B´aez, and C. P. Su´arez-Araujo, "Nonemail spam and machine learning-based anti-spam filters: trends and some remarks," in Proceedings of the International Conference on Computer Aided Systems 5eory, Springer, Las Palmas de Gran Canaria, Spain, February 2017.

39. M. Sasaki and H. Shinnou, "Spam detection using text clustering,"in Proceedings of the 2005 International Conference on Cyberworlds (CW'05), IEEE, Singapore, November 2005.

40. K. Narisawa, H. Bannai, K. Hatano, and M. Takeda, "Unsupervised spam detection based on string alienness measures," in Proceedings of the International Conference on Discovery Science, Springer, Sendai, Japan, October 2007.

41. P. Lison, An Introduction to Machine Learning, Language Technology Group, Edinburgh, UK, 2015

42. S. Smadi, N. Aslam, and L. Zhang, "Detection of online phishing email using dynamic evolving neural network based on reinforcement learning," Decision Support Systems, vol. 107, pp. 88–102, 2018.

43. Y.-F. Chiu, C.-M. Chen, B. eng, and H.-C. Lin, "An alliance based anti-spam approach," in Proceedings of the 5ird International Conference on Natural Computation (ICNC 2007), IEEE, Haikou, China, August 2007.

Review on Fog Investigation of Performance of Load Balancing Methods in the Computing Environment

Amreen M. Khan
Department of Computer Science and Engineering
G. H. Raisoni Institute of Engineering and Technology
Nagpur, Maharashtra
✉ Khanamreen67@gmail.com

ABSTRACT

In this paper, Fog computing is defined as, extending cloud computing abilities to the threshold of the community, toward the facts sources and giving up to customers. Unlike traditional cloud computing, where data processing and storage occur in centralized data centers, fog computing decentralizes these tasks, distributing them across a network of devices at the edge. This distributed architecture brings computing resources closer to where they are needed, decreasing latency, enhancing efficiency, and initiating real-time data processing for time-sensitive applications. Load balancing is a crucial issue of optimizing resource usage and enhancing average performance in fog computing environments. Fog computing extends traditional cloud architectures by decentralizing computation and storage abilities to the network's edge. Efficient load balancing guarantees that computational responsibilities are frivolously dispensed amongst fog nodes, preventing useful resource bottlenecks, minimizing latency, and improving the overall system's responsiveness. Various load balancing algorithms are explored in the context of fog computing, considering factors such as task characteristics, node capacities, and network conditions. These algorithms aim to distribute tasks efficiently, preventing individual nodes from becoming overloaded and ensuring a balanced utilization of resources. Dynamic adaptation to changing network conditions and workload fluctuations is a key feature of effective load balancing process in fog computing environments.

KEYWORDS *: Fog computing, Internet of Things (IoT), Resource management, Cloud computing, Load balancing.*

INTRODUCTION

The Internet of Things (IoT) represents a transformative paradigm in the realm of connectivity, converging physical devices, sensors, and everyday objects into a dynamic network capable of seamless communication and data exchange. This abstract provides an overview of key aspects related to IoT, including its architecture, applications, challenges, and future prospects. The architecture of IoT comprises interconnected devices equipped with sensors and actuators, enabling them to collect and transmit data. This data is then processed and analyzed either locally or in the cloud, facilitating informed decision-making. The communication protocols and standards that govern IoT interactions play a pivotal role in ensuring interoperability among diverse devices and platforms. IoT finds application in a myriad of domains, ranging from smart homes and healthcare to industrial automation and smart cities. Smart home devices, for example, enable users to remotely control appliances, while healthcare applications include remote patient monitoring and wearable health trackers. In industrial settings, IoT contributes to predictive maintenance and optimization of manufacturing processes, enhancing efficiency and reducing downtime. Despite its transformative potential, IoT encounters challenges such as security and privacy concerns, interoperability issues, and the sheer volume of data generated. Security protocols, data encryption, and standardization efforts are being implemented to address these concerns and establish a secure and reliable IoT ecosystem Looking ahead, the future of IoT involves advancements in edge computing, artificial intelligence, and 5G connectivity. Edge computing brings processing toward IoT devices, reducing latency and improving actual-time abilities. Artificial intelligence enables more intelligent data analysis, leading to predictive insights and automation. The deployment of 5G networks further accelerates data transfer speeds, fostering a more responsive and interconnected IoT landscape. This abstract offers a comprehensive overview of IoT, emphasizing its architecture, applications, challenges, and future directions. As IoT continues to evolve, its impact on various industries and daily life is composed to grow, ushering in a new age of connectivity to technology and data-driven innovation.

The Internet of Things (IoT) has delivered big records and analytics in a few years. By 2015, the Internet of Things will include more than 15 billion devices connected with sensors, making the operation of the network a must to manage. Connected gadgets include different wearable electronic devices (smart watches, various assistive devices, glasses), smart cities, smart grids for measuring home energy consumption, vehicle electronics and sensor connectivity. Cisco Systems announced that there will be 50 billion connected devices by 2020. However, in the present situation, various researchers have determined the count of fog near 2020, that is, there are nearly 31.73 billion hardware devices available by the end of 2020. These rates will start to increase from 15% to 50%. It will reach 150 billion in the next few years by 2030.

This tool additionally makes use of a whole lot of strength, which must be reduced to save you device failure. IoT information is saved and executes in cloud records facilities. However, cloud computing is most effective for initiatives that require excessive latency and few availability. The growth of IoT devices requires a program that could lessen records transmission and power intake in cloud data centers. Fog count is designed to serve low latency and excessive carrier to IoT customers. Fog computing is a relatively virtualized system that enables interaction between cloud information and IoT customers. The cloud layer connects to IoT near Bluetooth, WiFi and 4G LTE wireless network access.

As IoT systems expand, the increase in data volume, speed and diversity gives the growth to cloud applications [2]. The Internet of Things also requires real time communication to process and store the data produced by these smart devices. Fog computing supplies edge data center distribution, location awareness, distribution area, and other functions. The cloud layer consists of smart routers, small servers or other devices that enable data transmission in between the different devices [5]. Fog computing was invented in 2012 and is currently used in smart cities, smart healthcare, smart transportation, etc. It is widely used in areas.

RELATED WORK

Load balancing within the fog environment is a full-size vicinity of studies wherein many researchers gave their contribution. We've reviewed many survey papers inside the area of useful resource control load balancing in fog computing as well as cloud computing. In the load balancing technique of fog computing, not much work has been done till now. Most researchers have worked upon load balancing techniques. Right here we supplied the precis of current surveys carried out inside the area of cloud and fog computing Arunarani et al. studied special scheduling strategies of cloud computing. Different indicators of existing technologies are examined and the problems faced by these technologies are discussed. The survey compares data based on different technologies and decisions. The paper also highlights different research topics in cloud planning. This article only focuses specifically on planning technology. This article does not consider the balance and usage of resources in the cloud data center. Dey et al. [4] provide the study on present techniques of VM migration and their benefits and limitations along with their outcomes. The paper contains various statistical models and also analyzes the practical results. The survey of several parameters concerns, i.e. VM migration, performance, mean time and energy consumption either after or before host logouts. Gobai Alani et al. [2] reviewed different control systems for climate applications and provided a good review in taxonomy. The authors cognizance of numerous factors of aid management along with load balancing, scheduling and distribution, activity allocation, useful resource allocation and performance. Compare resource management techniques from various aspects: QoS metrics, tools, case studies, and technologies used. These methods were also compared with their advantages and disadvantages. Kumar et al. [6] conducted a review of air conditioning measurements. This article describes the different challenges faced in load balancing and their challenges. We did an analysis and divided the load test into different groups. The advantages, disadvantages, difficulties and details of these technologies are examined. Pulgebrai et al. [8] studied various load measurement methods for IoT. These technologies are parted into two types: centralized and decentralized. These technologies are compared from various aspects, good to bad, with QoS parameters, and the problems and search difficulties faced by customers are included. Chandak et al. [5] reviewed various measurement methods and gave a review of present methods. This article also examines this technology as a different measure of climate and presents a simulation tool to perform such measurements. Xiao et al. [6] investigated the differences between parallel, operational systems used in cloud computing. Attention has been drawn to the disadvantages of this process. Attention has been drawn to the disadvantages of this process. This article also discusses various problems encountered in the cloud computing load balancing process. This article does not address the difference from the perspective in the previous image. Hong et al. The architecture and infrastructure of cloud and edge computing are now being examined. This article also examines the various control systems available in the aerospace environment. This architecture is classified according to the level of information control and algorithm usage. They classified these models into hardware, system software and media. Algorithms are divided into groups such as: detection, evaluation, evaluation and placement. This article is mostly about architecture and infrastructure. There isn't much explanation of the algorithm, and there doesn't seem to be any comparison between existing algorithms. Mooradian et al. It provides a broad study of cloud computing. The author focuses on the latest technology in cloud computing. This article covers the algorithms, structure and simple principles of cloud computing. Many challenges are communicated and search tips are given. This article discusses Tactile Internet, a new technology that discusses the role of air. The article focuses on different algorithms of cloud computing but does not focus on the load balancing algorithm. On the basis of analysis of many research documents, we can conclude that there is no review of the assessment process to ensure the distribution and significance of this process in the air. In this article, we examine in detail the loading equation methods proposed by various researchers and discuss the research challenges they face.

PROPOSED WORK

Based on the explanation in the above section, we can say that more work needs to be done on balancing the atmosphere in the environment. We propose a cloud computing framework to achieve load balancing. Our proposed framework is an extension of cloud design where we use parallel objects in the cloud layer. Figure 1 shows the design model for stability in airspace. There are three layers in this model: end user, cloud layer and cloud layer. The description of the layers is as follows:

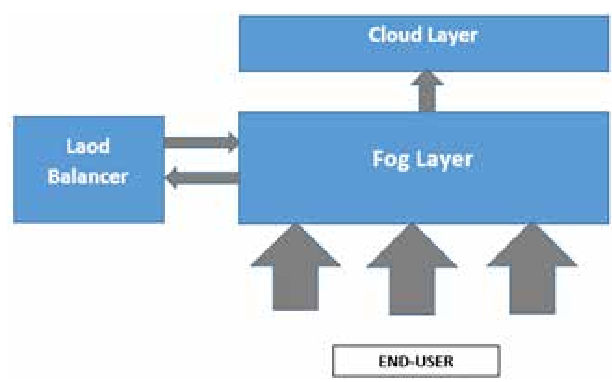


Fig 1: Fog computing architecture for load balancing

End users: The first layer consists of end users who create various requests. These users are IoT users; so they need to respond.

Fog Layer: Fog is the second layer with a central controller that controls all requests from end users. The central management manages the requests. End user requests are split into a set of tasks assigned to a load balancer. The load balancer controls the availability of resources in the cloud layer. Allocates tasks to virtual resources. If there is a lot of customer demand, some resources will be overused, while other resources will be underutilized. So the load balancer will transfer tasks from overused nodes to underused nodes. The load balancer tries to distribute client requests evenly across all services so that these requests can be processed immediately and clients can be responded to quickly. The cloud layer includes routers, nano data servers, and databases and also helps in storing, processing, and transmitting data to the cloud layer.

Cloud tier: Cloud tier has a large database that retrieves data from the cloud tier and stores it for later use and processing.

CONCLUSION

In this modern computing era with the increase of IoT, the necessary of load balancing extended in the fog computing surroundings in the fog computing structure, the fog is an intermediate layer between smart IoT devices and cloud layer which helps to execute actual-time records on the fog layer only, and in addition statistics are despatched to loud statistics centers, for storage and processing. Now and again workload at the fog layer is elevated because of extra IoT user requests, which are addressed smartly in order that IoT customers get a direct response in actual time. For this motive, load balancing is implemented within the fog layer in order that duties must similarly divide among all the processing nodes.

REFERENCES

1. Mandeep Kaur, and Rajni Aron, "A systematic study of load balancing approaches in the fog computing environment", The Journal of Supercomputing under exclusive licence to Springer Science+Business Media, LLC part of Springer Nature 2021.
2. Pooyan Habibi, Mohammad Farhoudi, "Fog Computing: A Comprehensive Architectural Survey," IEEE Access, VOLUME 8, 2020.
3. Sabireen H., Neelanarayanan V., "A Review on Fog Computing: Architecture, Fog with IoT, Algorithms and Research Challenges," Science Direct, ICT Express 7 (2021) 162–176,20 May 2021.
4. Redowan Mahmud, Ramamohanarao Kotagiri and Rajkumar Buyya,"Fog Computing: A Taxonomy, Survey and Future Directions", Springer Nature Singapore Pte Ltd. 2018 B. Di Martino et al. (eds.), Internet of Everything, Internet of Things, https://doi.org/10.1007/9 78-981-10-5861-5_5.
5. David Bermbach, Frank Pallas, David Garc ́ıa P ́erez, Pierluigi Plebani, Maya Anderson, Ronen Kat, and Stefan Tai., "A Research Perspective on Fog Computing", Conference Paper,November 2017,at malaga spain.
6. Amr Adel,"Utilizing technologies of fog computing in educational IoT systems: privacy, security, and agility perspective," Springer Open, Adel J Big Data (2020) 7:99.
7. Prakash P, Darshaun K.G, Yaazhlene. P, Medidhi Venkata Ganesh, Vasudha B., "Fog Computing: Issues, Challenges and Future Directions", International Journal of Electrical and Computer Engineering (IJECE) Vol. 7, No. 6, December 2017, pp. 3669~3673 ISSN: 2088-8708, DOI: 10.11591/ijece.v7i6.pp 3669-3673.
8. Prabhdeep Singh,Rajbir Kaur,Junaid Rashid,Sapna Juneja, Gaurav Dhiman,Jungeun Kim and Mariya Ouaissa,"A Fog-Cluster Based Load-Balancing Technique", Sustainability 2022, 14, 7961. https://doi.org/10.3390/su14137961, 29 June 2022.

CakeMeup App - Investigating the use of Flutter and Firebase for Developing E - Commerce Solution for a Cake Shop

Sprooha Athalye
✉ sprooha.Athalye@famt.ac.in

Gaurav Vaze*
✉ gauravvaze6774@gmail.com

Sanika Pawar
✉ sanikapawar236@gmail.com

Sakshi Kadam
✉ sakshikadam7796@gmail.com

Manali Jangale
✉ emanalijangale245@gmail.com

Computer Science and Engineering
Finolex Academy of Management and Technology
Ratnagiri, Maharashtra

ABSTRACT

This research examines utilizing Flutter and Firebase to develop the CakeMeUp e-commerce app for a cake shop, aiming for a seamless user experience. It reviews literature on consumer behavior trends in e-commerce and app development to contextualize the study. Implementation details cover the user workflow from login to order tracking, system architecture using Firebase's real-time database and Firestore collections, challenges faced like dependency management and performance optimization, and integration of the ikChatbot for personalized assistance. Key benefits of using Flutter and Firebase highlighted include high performance, cross-platform capabilities, attractive UI design, scalability through serverless architecture, and strong community support. The app's core features encompass an intuitive ordering process, secure payment gateways, cake customization, user-friendly chatbot, and admin panel. Despite challenges, Flutter and Firebase enable creating innovative, user-centric e-commerce solutions by leveraging their strengths in mobile app development and cloud infrastructure. Continuous improvements are necessary to meet evolving consumer needs in the competitive landscape.

KEYWORDS *: Flutter, Firebase, Dart, E - Commerce, Chatbot.*

INTRODUCTION

Flutter and Firebase have emerged as powerful tools in the realm of mobile app development. Flutter enables the creation of natively compiled applications for various platforms using a single codebase. Firebase, a comprehensive mobile and web application development platform, provides a robust backend infrastructure with features like real-time database, authentication, and cloud functions.

The proposed E-Commerce solution aims to revolutionize the cake shopping experience by combining the best of Flutter's user interface capabilities and Firebase's robust backend services. By harnessing Flutter's reactive programming model and Firebase's real-time data synchronization, the app promises a truly dynamic and immersive experience for users. Moreover, the integration of cloud-based services like Firebase Cloud Storage and Firebase Hosting ensures scalability and efficient resource management, crucial for handling varying traffic and data loads typical of e-commerce platforms.

The proposed E-Commerce solution for a cake shop leverages the strengths of Flutter and Firebase to deliver a seamless and dynamic user experience.[7] It incorporates features such as a visually appealing and responsive UI, real-time updates on order status, secure authentication for user accounts, and efficient data storage through Firebase's real-time database. Additionally, the app integrates Dart, the programming language used by Flutter, ensuring high-performance execution.

The innovative aspects of the app extend to the incorporation of a chatbot. This chatbot, designed for enhancing user interaction, will provide a personalized and interactive shopping experience, making the E-Commerce platform more engaging and user-friendly[8].

LITERATURE REVIEW

The paper "A Study of Consumer Behavior Towards Food Ordering And Delivery Platform" aimed to understand consumer preferences and factors influencing online food ordering decisions. 129 respondents provided information via surveys and online sources. It found social media greatly influences customers. To maintain satisfaction, platforms should fix technical issues, enhance site performance, delivery windows, and provide attractive offers.[1]

The paper "A Study On The Impact Of Covid-19 On Home Delivery Of Food Items Through Food Delivery Platforms" discussed customers' reluctance to order food online due to fears of infection and concerns about delivery personnel's cleanliness during the Covid-19 outbreak. It contrasted acceptance criteria of those who placed and didn't place online orders.[2]

The paper "Digital Food Service Application: It's Influence and Challenges Faced by Consumers" investigated consumer behavior in retail and e-commerce using methods like structural equation modeling and questionnaires. It proposed a theoretical model based on frameworks to examine factors influencing consumer attitudes and intentions towards online food delivery services.[3]

The paper "Implementation E-Commerce in Cake Shop" discusses an online cake ordering system that simplifies buying cakes, arguing that making businesses internet-accessible with 24/7 online services can expand product ranges and improve customer access.[4]

The paper "Developing an E-Commerce Application Using Flutter" presents a case for using Flutter in e-commerce app development, highlighting its cross-platform capabilities, cost-effectiveness, engaging UIs, and outlining steps for developing a Flutter-based e-commerce app.[5]

"Food Ordering Mobile Applications – A new wave in Food Entrepreneurship" reports a survey finding 95% user awareness of mobile food ordering apps, with benefits for businesses but challenges from customer reviews. It analyzed aspects like usage, business volume, and delivery effectiveness.[6]

IMPLEMENTATION DETAILS

User Workflow

The CakeMeUp app's user flow, as depicted in Figure 1, starts with the login interface where users can create a new account by providing phone number, name, and address details or log in if already registered. Upon successful login/registration, users access the main System UI to browse through various cake items. They can add selected cakes to the cart and proceed to the 'Buy' option when ready for purchase.

Two primary payment methods offered are Cash on Delivery (COD) and UPI/Net banking for the user's preferred mode. After payment, users get the 'Track Order' feature to monitor the real-time status and location of their cake delivery. The UI allows navigating cake varieties, adding to cart,choosing payment method, and tracking orders seamlessly.

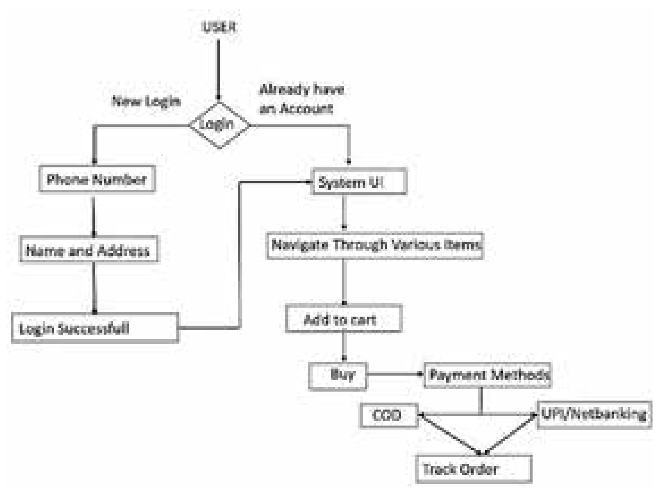


Fig. 1 User Worflow Flow Daigram

Architectural Description

1) Backend: The backend of CakeMeUp utilizes a cloud-hosted Firestore Database, a NoSQL document database offered by Firebase. The database logically partitions into multiple collections for storing diverse data types:

- RatnagiriCakes and ChiplunCakes: Dedicated to storing cake information from Ratnagiri and Chiplun regions, allowing efficient data management and retrieval based on geographical locations.
- RatnagiriOrders and ChiplunOrders: Similar to cake collections, designed to store order data specific to Ratnagiri and Chiplun regions, ensuring efficient order tracking and management based on respective regions.
- Users: Responsible for storing user-related data like profiles, preferences, and order histories, facilitating personalized experiences and maintaining user interaction records.

2) Frontend: The CakeMeUp app's frontend develops using Flutter, a cross-platform framework for building mobile applications. Flutter enables creating a responsive and visually appealing user interface (UI) deployable on web and Android platforms, serving as the primary interface for browsing cakes, placing orders, and interacting with the application.

3) Other Services: Two third-party services integrate to enhance functionality and user experience:

- RazorPay: A popular online payment gateway service in India, incorporated to facilitate secure online payments for cake orders placed through the app, ensuring a seamless payment experience and reducing purchase abandonment risk.
- ikChatbot: This service integrates to provide customer support and address user queries or reviews related to the cake shop's products and services, aiming to enhance the overall customer experience by offering real-time assistance and addressing potential concerns or questions during the ordering process.

The proposed architecture, as shown in Fig 2, leverages cloud-based databases, cross-platform mobile development frameworks, and third-party services to deliver a comprehensive and user-friendly cake ordering system.

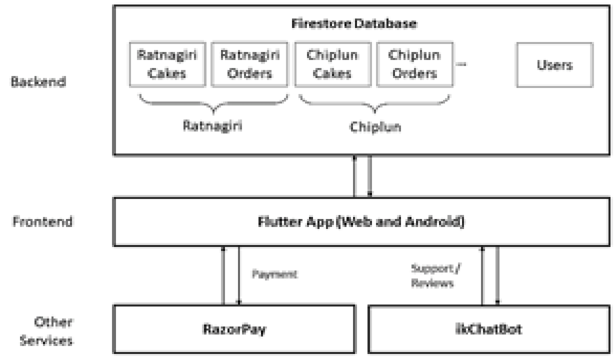


Fig. 2. User Flowchart

Problems Encountered

1. Dependency upgrades with breaking changes: As Flutter evolves rapidly, updating for new features led to breaking changes with new versions incompatible with previous ones. This caused code conflicts, deprecated methods, and behavior changes requiring careful codebase modifications. Effectively managing these updates became crucial for a stable, up-to-date application.
2. State Management: Flutter's reactive programming model and the use of streams and providers can be challenging when working with real-time data from Firebase Realtime Database or Firestore. Managing state across different parts of the application and ensuring consistent data flow can be complex
3. Handling Image Assets and Performance Optimization: Loading and displaying images efficiently is crucial for a visually appealing E-Commerce app. Flutter, being a UI-centric framework, requires thoughtful handling of image assets to prevent performance bottlenecks. Issues like slow image loading times and improper caching aroused.
4. Integration and Testing of Chatbot Functionality: Seamlessly integrating a chatbot required addressing UI, UX, and conversational flow issues. Ensuring accurate query understanding and relevant responses involved rigorous testing and iterative refinement. Handling potential chatbot misinterpretations or comprehension failures required thoughtful consideration during development and testing.

5. Cross-Platform Compatibility: While Flutter aims to provide a consistent experience across platforms, there may be platform-specific nuances or dependencies that need to be addressed, especially when integrating with native functionality or third-party libraries

Benefits

1. High Performance and Native-Like User Experience: Flutter uses a compiled language (Dart) to achieve high-performance execution and near-native performance on both Android and iOS platforms, ensuring smooth animations and fluid user interactions for a native-like user experience.
2. Scalability and Serverless Architecture: Firebase's serverless architecture eliminates the need for managing servers and infrastructure, automatically scaling to accommodate varying workloads and ensuring efficient resource utilization for E-Commerce applications.
3. Sunning UIs: Flutter's widget-based approach and rich set of customizable widgets make it easier to create visually appealing and responsive user interfaces. This is crucial for the cake shop app, where attractive UI design can enhance the user experience and potentially drive more sales.
4. Cross-platform development: Flutter's cross-platform capabilities enable developing a single codebase deployable on Android, iOS, and web platforms. This streamlines the development process, reduces time and costs, and ensures a consistent user experience across devices and operating systems.
5. Strong Community Support: Flutter has a vibrant and rapidly growing community of developers, providing a wealth of resources, documentation, and third-party packages, enhancing the learning experience and ensuring the framework stays up-to-date with industry trends.

RESULTS

Features of the App

1. Attractive and user-friendly UI: The app will feature a visually appealing and intuitive user interface, designed using Flutter's extensive collection of customizable widgets, ensuring a polished and engaging experience for users.
2. Hassle-free order process: The app will provide a seamless order process, leveraging Firebase's real-time database to synchronize order information and inventory across devices in real-time, ensuring a smooth and efficient experience for customers.
3. Secure payment gateway with COD available: The app will integrate secure payment gateways, including the option for Cash on Delivery (COD), facilitated by Firebase's authentication and authorization features for implementing robust access control and user roles.
4. Cake customization options: Users will have the ability to customize their cake orders through a user-friendly interface, with the backend logic for processing customization requests handled by Firebase's Cloud Functions.
5. User-friendly chatbot: The app will incorporate a chatbot feature, developed using Flutter's widget library and Firebase's real-time database, to provide users with a conversational and user-friendly experience for inquiries and assistance.
6. Refi admin panel: An administrative panel will be included in the app, leveraging Flutter's cross-platform capabilities and Firebase's real-time database, allowing administrators to manage orders, inventory, and user data efficiently.

B. ikChatBot

The cake shop app integrates ikChatbot to serve these purposes:

1. Obtaining customer reviews: The chatbot gathers feedback and opinions from users about the app, ordering process, and cake quality. This helps identify areas for improvement and understand customer satisfaction levels.
2. Providing assistance: It offers real-time support and troubleshooting to users. Additionally, it provides order status updates and guidance on using various app features.
3. Recommending cakes/flavors: Based on user preferences, dietary needs, or occasion requirements, the chatbot suggests suitable cakes

or flavors. This personalized recommendation enhances the user experience.

4. Addressing inquiries: It responds to a diverse range of user questions related to products, services, pricing, and more. Prompt resolution of queries improves customer satisfaction.

5. Soliciting feedback: The chatbot collects user opinions on specific aspects of the app, such as UI, navigation, or new functionalities. This feedback aids in making informed decisions for future app enhancements.

Output

Upon initial app launch, users encounter the login screen, requesting phone number and additional information if not previously registered, as depicted in Figure 3.

Fig. 3 Login and Personal Details

After successful login, users gain access to browse the bakery's full catalogue, including detailed item information as illustrated in Figure 4.

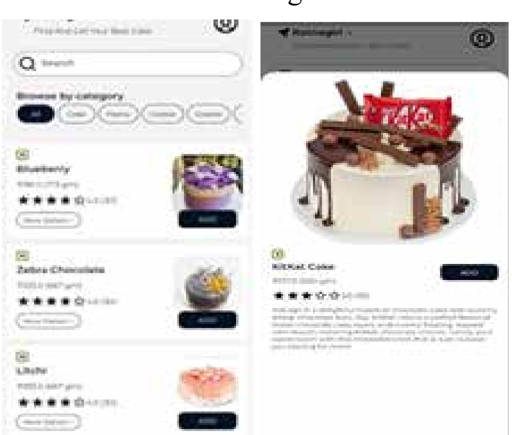


Fig. 4 Bakery Catalogue and Cake Details

Users possess the ability to add desired items to their cart, customize quantities, and subsequently advance to the checkout process.

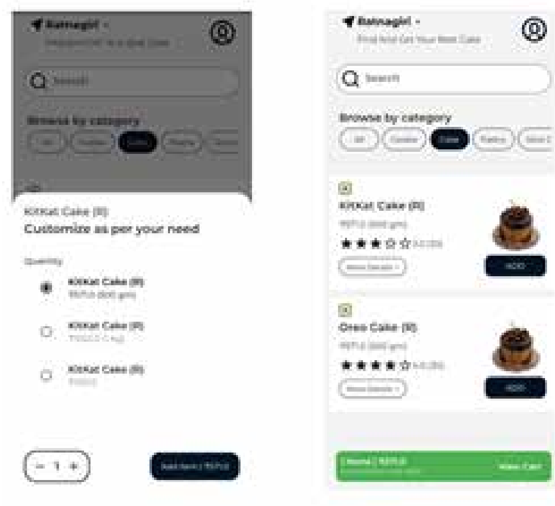


Fig. 5 Adding Cakes to the Cart

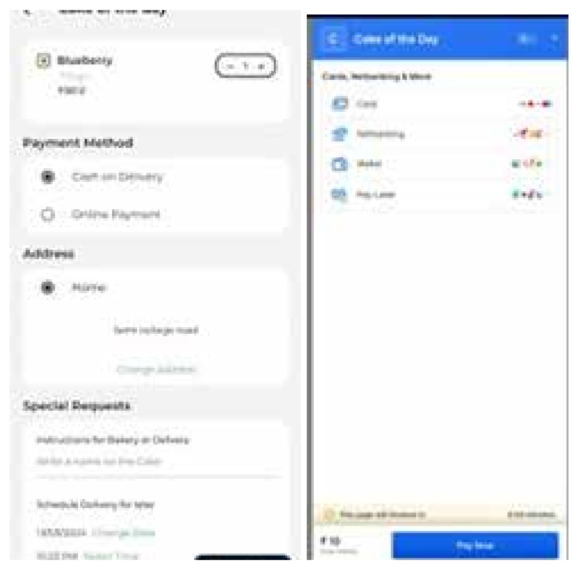


Fig. 6 Proceeding to Checkout and Payment Gateway

CONCLUSION

In summary, this research explores the adoption of Flutter and Firebase in crafting an E-Commerce solution tailored for a cake shop's needs. Through an in-depth analysis of relevant literature and implementation specifics, we have outlined the strengths and challenges associated with these technologies. Flutter facilitated the creation of a responsive and visually engaging user interface, while Firebase provided a scalable backend infrastructure with real-time database capabilities. Despite facing challenges such as dependency upgrades, state management complexities, and performance optimization issues, the benefits of Flutter and Firebase, including high performance, scalability, and cross-platform development, outweighed the drawbacks. The developed app offers features like seamless order processing, secure payment options, cake customization, and user-friendly chatbot assistance, enhancing the overall customer experience. Continuous updates and improvements will be necessary to address emerging trends and evolving consumer preferences in the competitive E-Commerce landscape. Overall, this research underscores the significance of Flutter and Firebase in building innovative and user-centric mobile applications, paving the way for future advancements in E-Commerce solutions.

REFERENCES

1. Sayali Pachpute, "A Study Of Consumer Behaviour Towards Food Ordering And Delivery Platform", International Journal of International Institute of Management Studies / Vol 2/ Issue 1/ JAN/ 2023.
2. Ashish Kumar ,"A Study On The Impact Of Covid-19 On Home Delivery Of Food Items Through Food Delivery Platforms", Palarch's Journal Of Archaeology Of Egypt/Egyptology 17(12) 2020.
3. Atin Das, Balla Ushasri , Umesh Sharma, "Digital Food Service Application: It's Influence and Challenges Faced by Consumers", Journal of Tourism & Hospitality
4. Akash, Prof. Saraswati R Bhusanur, "Implementation E- Commerce In Cake Shop", International Research Journal of Modernization in Engineering Technology and Science, Volume:04/Issue:07/July-2022.
5. J. Singh et al., "Flutter and Firebase Making Cross-Platform Application Development Hassle-Free," International Research Journal of Modernization in Engineering Technology and Science, vol. 4, no. 4, pp. 1819-1827, Apr. 2022
6. Dr. Sonali Jadhav, "Food Ordering Mobile Applications – A new wave in Food Entrepreneurship", International Journal of Latest Technology in Engineering, Management & Applied Science (IJLTEMAS) Volume VII, Issue IV, April 2018.
7. S. Sayali and P. Athalye, "Consumer behavior analysis towards online food ordering platforms," International Journal of Engineering Research and Applications, vol. 12, no. 7, pp. 23-29, Jul. 2022.
8. A. Das, B. Ushasri, and U. Sharma, "Digital food service apps: Influencing factors and consumer challenges," Journal of Tourism & Hospitality, vol. 10, no. 3, pp. 117-128, Mar. 2021.
9. "FireBase Documentation," Firebase.google.com [Online]. https://firebase.google.com/docs. [Accessed: 14-June-2023].
10. "Flutter Documentation," Flutter.dev. [Online]. Available: https://flutter.dev/docs. [Accessed: 14-June-2023].

Explainable AI-Enhanced Predictive Modelling for Custom Motorcycle Pricing: A Machine Learning Approach

Varsha Jadhav*
✉ varsha.jadhav@viit.ac.in

Yash Kadam
✉ yash.22220009@viit.ac.in

Omkar Khade
✉ bomkar.22110174@viit.ac.in

Suraj Patil
✉ suraj.22110119@viit.ac.in

Department of Artificial Intelligence and Data Science
VIIT
Pune, Maharashtra

ABSTRACT

This study presents a machine learning model for predicting custom motorcycle prices based on various specifications. These include brand, model name, max power, max torque, fuel tank capacity, top speed, front brake type, kerb weight, overall length, overall width, wheelbase, and overall height. The model aids both buyers and sellers in determining fair prices by considering market trends and demand. Using a dataset containing comprehensive information on custom bikes and their prices, the research employs explainable AI techniques such as LIME and SHAP to enhance interpretability. SHAP values are calculated to understand feature importance globally, depicted through visual SHAP summary plots. LIME offers local interpretability, providing explanations for specific instances in the test data. The integration of these techniques results in a transparent machine learning model. The Random Forest Regressor (RFR) is identified as the optimal algorithm, with a notable R-squared score of 0.87 and a cross-validation score of 0.82, indicating robust performance on both training and testing data. The developed model is encapsulated in a Flask app, enabling users to input custom bike specifications and promptly receive price estimates. This approach fosters transparency and informed decision-making in the custom motorcycle market.

KEYWORDS *: Custom bike, Machine learning, Random forest regression, Flask, Explainable AI.*

INTRODUCTION

The market for custom bikes has been growing steadily in recent years as people are looking for unique and personalized vehicles. But depending on several variables, like the kind of bike, the brand, and the specs, bespoke bike costs can differ dramatically. Therefore, it is crucial to develop a system that can accurately predict the price of a custom bike.

Machine learning has shown tremendous potential in predicting prices in various industries, and the custom bike market is no exception. By using machine learning algorithms, we can analyze historical data and make predictions about the price of a custom-built motorcycle. This can help potential buyers and sellers to have a better understanding of the market value of a custom bike.

In this research paper, we present an innovative software solution for custom bike price prediction using machine learning techniques. Our system utilizes a comprehensive dataset of custom bike specifications and prices to train a machine learning model. Based on the features of a custom bike, the model can accurately predict its price. The paper will also discuss the methodology used in collecting and cleaning the data, feature selection, model selection, and performance evaluation. By the end of this paper, readers will have a better understanding of how machine learning can be used to predict the price of custom bikes accurately.

The software solution we have developed is user-friendly and can be used by custom bike manufacturers, dealers, and enthusiasts. The system can help in making informed decisions about pricing, buying, and selling custom bikes. The accuracy of the price prediction can help in eliminating the risk of overpricing or underpricing, which can lead to financial losses. In addition, our commitment to transparency is evident through the incorporation of Explainable AI (XAI) methods in our model. This ensures that the decision-making process of our custom bike price prediction model can be interpreted and understood. XAI methods provide insights into how the model arrives at its predictions, enhancing user trust and facilitating a deeper understanding of the market dynamics. The findings of this study can assist buyers and sellers make wise decisions by offering insightful information about the custom bike industry. Furthermore, this study may be used as a guide for next studies on price prediction in the custom bike market.

The main objective is to develop a model that can precisely estimate the price of a motorbike that has been customized by considering several variables, including the kind of bike, the parts that are utilized, and the degree of customization. Custom motorcycle purchasers and builders may use this model to estimate the cost of a custom bike, which will aid them in the decision-making and bargaining processes. The intention is to improve the efficiency and transparency of the custom motorcycle industry by developing a tool that can offer a trustworthy and accurate estimate of the cost of a motorbike.

Developing a predictive model that can reliably estimate the cost of custom bikes based on features like the name, brand, maximum power and torque, fuel tank capacity, top speed, type of front brake, kerb weight, overall length, overall width, wheelbase, and overall height is the aim of this study on custom bike price prediction. The machine learning model will be trained and validated by the study using a dataset of historical custom bike data. The intention is to give specialized bike builders and bike lovers a trustworthy and precise tool for estimating the worth of their bikes or prospective acquisitions. Furthermore, this research will highlight the advantages of applying machine learning and investigate its possible uses in the automobile sector.

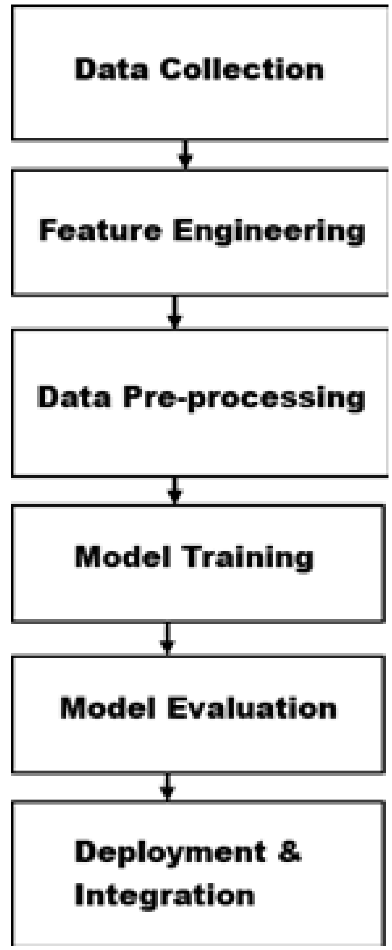


Fig. 1. Block Diagram for Custom Bike Price Prediction [9]

CUSTOM BIKE PRICE DATASET

To train and test the custom bike price prediction model, we collected datasets from various sources, including online marketplaces, manufacturer websites, and customer reviews. The datasets contain information about various features of custom bikes, such as the name, brand, max power, max torque, fuel tank capacity, top speed, front brake type, kerb weight, overall length, overall width, wheelbase, and overall height.

We cleaned and preprocessed the datasets to remove any inconsistencies and missing values. The final datasets consist of 173 custom bikes with 13 features each. Figure 2 shows a sample of the dataset.

	name	brand	price	max power	max torque	fuel tank capacity	top speed	front brake type	kerb weight	overall length	overall width	wheelbase	overall height
0	Royal Enfield Hunter 350	Royal Enfield	149900	20.20	27.0	13.0	114.0	disc	177.0	2055	800.0	1370	1055
1	Royal Enfield Classic 350	Royal Enfield	190229	20.20	27.0	13.0	114.0	disc	195.0	2145	785.0	1390	1090
2	Royal Enfield Bullet 350	Royal Enfield	157391	19.10	28.0	13.5	110.0	disc	186.0	2170	810.0	1395	1120
3	Royal Enfield Continental GT 650	Royal Enfield	304945	47.00	52.0	12.5	169.0	disc	198.0	2122	744.0	1398	1024
4	Royal Enfield Meteor 350	Royal Enfield	200924	20.20	27.0	15.0	112.0	disc	191.0	2140	845.0	1400	1140
...	...	...	...	...	...	...	...	...	...	...	...	...	...

Fig 2. Dataset of custom bikes

RELATED WORK

The utilization of machine learning methods to forecast the costs of different goods and services has gained popularity in the last few years. Research on forecasting car costs has been done on several occasions; custom bikes and cars have a lot in common. In this field, some pertinent works include:

Machine learning has shown tremendous potential in predicting prices in various industries, and the custom bike market is no exception. By using machine learning algorithms, we can analyze historical data and make predictions about the price.

- Pudaruth's study (2014) [1] delves into supervised machine learning to forecast the cost of used cars in Mauritius, making use of decision trees, naive Bayes, k-nearest neighbors, and multiple linear regression. Despite the seemingly simple task, all four methods yield comparable performances, highlighting the challenges involved. While recognizing the difficulty in achieving high accuracy, the study sets the stage for future exploration of more sophisticated algorithms to enhance predictive capabilities in this domain. Pudaruth's research contributes significantly to advancing effective machine learning approaches for predicting used car prices.
- In Xu et al.'s (2019) exploration of Explainable AI (XAI), [2] the paper traces the historical evolution from expert systems to contemporary deep learning, emphasizing transparency needs in real-world applications. The study explores current state-of-the-art methods and important research areas, contributing valuable insights as XAI gains prominence. It concludes with a discussion on difficulties and potential paths, significantly advancing the comprehension and advancement of explainable AI systems.
- Bhagirath et al. (2021) study, "Indian Market Price Forecasting for Online Resale Bikes " [3] addresses the challenge of accurately estimating bike prices on platforms like OLX, emphasizing the complexity of pre-owned bike data. By employing Decision Tree and Linear Regression techniques on OLX India's data, they enhance accuracy, with Linear Regression showing superior precision through statistical parameters Mean, Variance, and Standard Deviation. This work significantly contributes to improving pre-owned bike price predictions in the dynamic online resale market.
- Linardatos et al. (2021) provide a thorough analysis in " Explainable AI: An Overview of Interpretability Techniques for Machine Learning" [4] addressing

the challenges of increasing AI complexity leading to "black box" models. Emphasizing the resurgence of interest in Explainable Artificial Intelligence (XAI), the study focuses on interpreting machine learning models for transparency. With a literature review and taxonomy of interpretability methods, the authors contribute a valuable resource for theorists and practitioners seeking insights into XAI implementations, aiming to mitigate the opacity associated with advanced machine learning systems.

- Chang Gao and Yong Chen (2022) " Predicting Bike Sharing Demand with Machine Learning Techniques" [5] suggests using four machine learning models - linear regression, random forest, k-nearest neighbors (KNN), and support vector machine - to predict consumer demand for bike sharing in Seoul. The approach is based on machine learning. By adding variables other than weather, like air pollution, traffic data, Covid-19 cases, and social and economic factors, we hope to improve earlier studies on bike sharing demand and improve prediction accuracy.
- In Bukvić et al.'s (2022) research on " Supervised machine learning for the prediction and classification of used car prices" [6] they tackle the challenge of used-car price prediction in a growing market. Using data from "Njuškalo," the Croatian online seller, and employing supervised machine learning, they achieve a noteworthy 95% prediction accuracy with linear regression. Their study sheds light on key factors like kilometers traveled and the year of production, contributing valuable insights to the comprehension of used vehicle pricing dynamics in a specific market context.
- Carta et al.'s (2022) study, "Explainable AI for Financial Forecasting" [7] navigates the challenges of financial feature engineering using machine learning. Emphasizing the low correlation between financial data features and labels, the paper employs explainable artificial intelligence (XAI) for automatic feature selection. The focus on predicting next-day returns for diverse stocks incorporates machine learning to develop effective feature selection strategies. This work contributes substantially to XAI in financial forecasting, showcasing its potential for identifying relevant features and enhancing prediction performance.
- Shaprapawad et al. (2023) enhance car price prediction via machine learning [8], addressing overfitting with regularization. Their study deploys diverse models, highlighting the support vector regressor's optimal performance (R2: 95.27%, MAE: 0.142, MSE: 0.047, RMSE: 0.218). Focusing on factors like mileage and manufacturing year, it delivers a reliable tool for sellers, buyers, and manufacturers, showcasing machine learning's efficacy in predicting used car prices.

While these studies focused on predicting the prices of automobiles, their approaches and techniques can be adapted to custom bikes. However, custom bikes have unique features and characteristics that require specific considerations. In the following section, we describe our proposed approach for predicting custom bike prices using machine learning.

METHODS

Machine Learning Model Training

We trained four different regression models to predict the price of a bike:

- Random Forest Regressor (RFR): The Random Forest Regressor is one machine learning strategy that is widely applied to regression issues. To make a final forecast, it builds several decision trees during the training phase and averages the predictions made by each tree. For predicting the cost of a custom bike given its specifications, we could build a model using the Random Forest Regressor.
- Decision Tree Regressor (DTR): Another machine learning approach for predicting custom bike prices is the Decision Tree Regressor. Recursively dividing the dataset into smaller subsets according to the input feature values is how it operates. This process is continued until each subset either reaches a maximum depth or only has one target variable value. Both continuous and categorical data can be handled by the non-parametric Decision Tree Regressor technique. Additionally, it can record

nonlinear correlations between the input features and the target variable.

- Adaptive Boosting Regressor (ABR): A machine learning technique called Adaptive Boosting Regressor, or AdaBoost, is applied to both regression and classification issues. It is an ensemble learning algorithm that builds a strong model by combining several weak models. In the case of regression, the weak models are decision trees. the algorithm takes in the dataset containing the features and the corresponding prices. Training and testing sets of the dataset are separated. The training set is then used by the method to train several decision tree models. After every model is trained, the weights of the training examples are changed to priorities the examples that were incorrectly classified. The final model is formed by summing the weights of the weak models.
- Elastic Net Regressor (ENR): Like the other regression algorithms previously described, a machine learning algorithm called Elastic Net Regressor is utilized in regression analysis. It combines the features of both Ridge and Lasso regression models, and it uses a penalty term that combines L1 and L2 regularization techniques. In the context of custom bike price prediction, the Elastic Net Regressor can be used to estimate a custom bike's cost based on several factors, including the name, brand, max power, max torque, fuel tank capacity, top speed, front brake type, kerb weight, overall length, overall width, wheelbase, and overall height. The algorithm can determine how these attributes and the bike's price relate to each other from a training dataset and then predict the price of a new bike with similar features.

The transformers used in the pipeline are:

- Column Transformer: Used to apply various transformers to various data columns.
- Standard Scaler: used to improve the uniformity of the numerical data.
- One Hot Encoder: utilized for encoding categorical data.

The first step in the process was to preprocess the data using Column Transformer to one-hot encode the categorical features and scale the numerical features. We used StandardScaler() to standardize the numerical data, OneHotEncoder(sparse=False, handle_unknown='ignore') to one-hot encode the categorical data.

We created two different ColumnTransformer() instances, one for each model type. The first column transformer, trf1_RFR, is used to transform the data before training the RFR and ENR models, and the second column transformer, trf1_DTR, is used to transform the data before training the DTR and ABR models.

We then created the four regression models using the following algorithms:

- RFR: RandomForestRegressor(n_estimators=200, * criterion='squared_error')
- DTR: DecisionTreeRegressor(random_state=42)
- ABR: AdaBoostRegressor()
- ENR: ElasticNet(alpha = 0.1, l1_ratio = 0.5)

We created four pipelines, one for every regression model, utilizing the corresponding regression model and the two column transformers that were previously made.

We used the test data to make predictions, the training data to train each pipeline, and the R-squared score to assess each model's performance. For a more comprehensive understanding of each model's ability to generalize to previously unseen data, we also employed cross-validation with 15 folds.

Model Integration

A Flask app included in this project allows users to communicate with the machine learning model by providing custom input parameters and getting a price prediction in response. The Flask app is a web framework that allows the creation of web applications in Python.

The Flask app uses the pickle library to load the trained machine learning model from a saved file, so that the app can use it to make predictions. This means that the trained model is integrated with the Flask app and can be accessed through it.

There are two HTML templates in the Flask application: home.html and result.html. Which offer the user interface for setting input parameters and showing the estimated cost. The home.html template contains a form that allows the user to enter the input parameters required to make a price prediction. Once the user has entered the input parameters, they can submit the form to the Flask app.

When the user submits the form, the Flask app takes the input parameters, and the machine learning model uses them to make a price prediction. The predicted price is then displayed on the result.html template. This template is responsible for displaying the predicted price in a user-friendly format, so that the user can easily understand the output.

XAI Methods

In the pursuit of enhancing the interpretability of our machine learning model dedicated to predicting bike prices, we incorporated an Explainable Artificial Intelligence (XAI) approach. This integration featured two prominent techniques, namely LIME (Local Interpretable Model-agnostic Explanations) and SHAP (SHapley Additive exPlanations). For the SHAP component, a Random Forest Regressor was trained on the relevant bike features, and SHAP values were subsequently computed using the SHAP library for the test dataset. In order to learn more about how the model makes decisions, a comprehensive summary plot was generated using the calculated SHAP values. This involved creating an Explainer object, utilizing the shap.Explainer class, and employing the shap.summary_plot function, where the feature_names parameter aided in providing clear identification of the features involved.

Concurrently, the LIME technique was integrated, involving the creation of a LIME explainer object (explainer_lime) through the LimeTabularExplainer class, configured specifically for tabular data and regression. The subsequent utilization of the explain_instance method facilitated the generation of a local explanation (exp) for a chosen instance in the test dataset, contributing to a more localized and granular understanding of model predictions.

SHAP (SHapley Additive exPlanations)

The foundation of SHAP values is cooperative game theory and assign a unique value to each feature, representing its contribution to the prediction. The Shapley value of a feature is calculated by considering all possible permutations of feature combinations. The Shapley value ensures a fair distribution of credit among the features.

$$\phi_i(f) = \sum_{S \subseteq N \setminus \{i\}} \frac{|S|!\,(|N|-|S|-1)!}{|N|!} \left[f(S \cup \{i\}) - f(S) \right] \quad (1)$$

where $\phi_i(f)$ is the Shapley value of feature i, N is the entire set of features, and f(S) is the model prediction for the subset of features S.

LIME (Local Interpretable Model-agnostic Explanations)

LIME manipulates the input features and tracks the changes in the model's output to create local, interpretable models around particular instances. It uses a simpler, more interpretable model to approximate the behaviour of the model locally.

$$\hat{g}(x) = arg\,min_g L\left(f,\ g,\ \pi_x\right) + \ \Omega(g) \quad (2)$$

Where:

- $\hat{g}(x)$ is the interpretable model's output for instance x,
- L is a loss function measuring the difference between the prediction of model f (x) and the interpretable model's predictions,
- π_x represents the perturbed instances near x,
- $\Omega(g)$ is a penalty term encouraging simplicity.

RESULTS & EVALUATION

Screenshot of the UI functional prototype

Fig. 3. Output 1

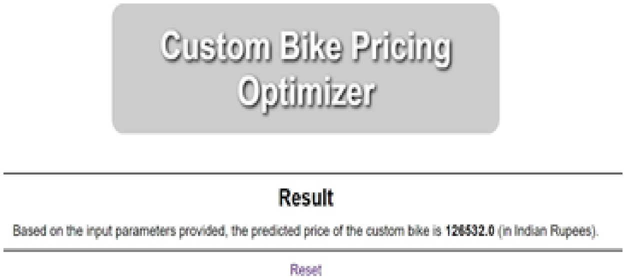


Fig. 4. Output 2

Machine Learning Model Evaluation:

Following the four regression models' training and testing, the following outcomes were discovered:

Table 1. R-square and Mean R-squared Cross-validation

Model	R-square	Mean R-squared Cross-validation
Random Forest Regressor (RFR)	0.87	0.82
Decision Tree Regressor (DTR)	0.95	0.69
Adaptive Boosting Regressor (ABR)	0.90	0.75
Elastic Net Regressor (ENR)	0.74	0.71

The below graphs illustrate R-squared and cross-validation scores for Random Forest, Decision Tree, AdaBoost, and Elastic Net Regression.

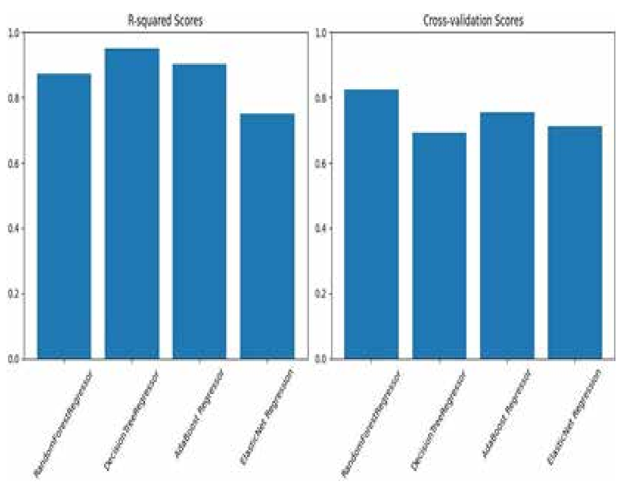


Fig. 5. Graph of R-squared Scores & Cross-validation Scores comparison for different regression algorithms

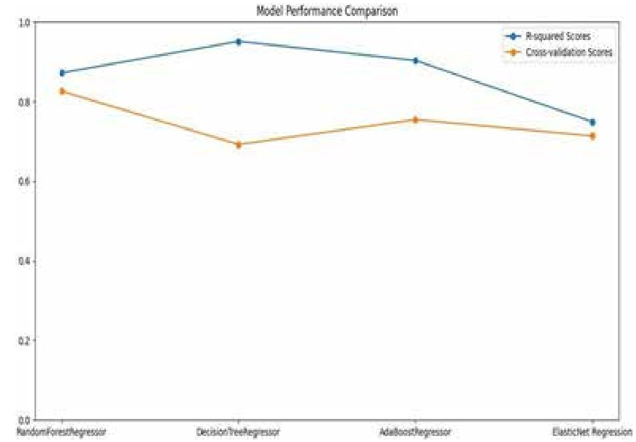


Fig. 6. Graph of Model Performance Comparison

Based on the results the Random Forest Regressor (RFR) appears to be the best-performing algorithm for this problem. It has an R-squared score of 0.87, which indicates that the model explains 87% of the variability in the target variable. Moreover, the mean R-squared cross-validation score of 0.82 (82%) suggests that the model performs well in terms of generalization.

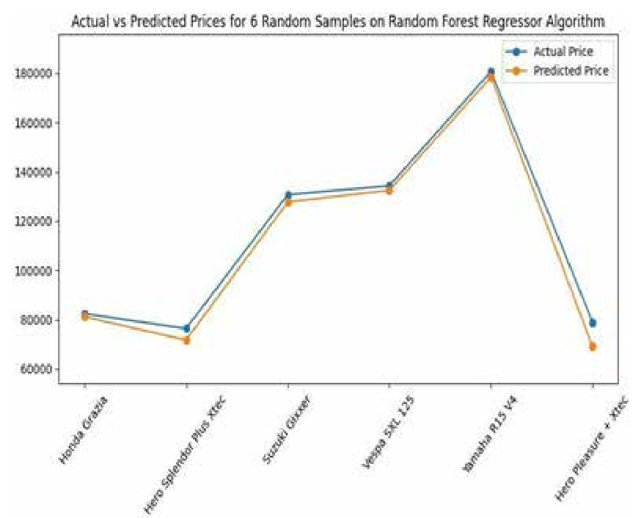


Fig. 7. Graph of Actual vs Predicted Prices for 6 Random Samples on Random Forest Regressor Algorithm

However, it is worth noting that the Decision Tree Regressor (DTR) has the highest R-squared score of 0.95, which is a strong indication that the model fits the training data very well. However, its mean R-squared cross-validation score of 0.69 indicates that it might overfit to the training data, which could lead to poor performance on new data.

The AdaBoost Regressor (ABR) also has a high R-squared score of 0.90, but its mean R-squared cross-validation score of 0.75 is lower than that of the RFR, indicating that the model might not generalize as well to new data.

The Elastic Net Regressor (ENR) has the lowest R-squared score of 0.74 and a mean R-squared cross-validation score of 0.71, indicating that it might not be the best choice for this problem.

Overall, the Random Forest Regressor (RFR) appears to be the best option for this problem based on the results, as it has a good balance between R-squared score and mean R-squared cross-validation score, indicating good performance on both the training and testing data.

Explainable AI (XAI) Performance

The combined SHAP and LIME approach offers both a global overview of feature importance for the entire dataset and a localized insight into specific instances, collectively enriching the interpretability of our machine learning model.

In the following graph, the SHAP graph illustrates the overall impact of each feature on price prediction, with top-influencing features displayed prominently.

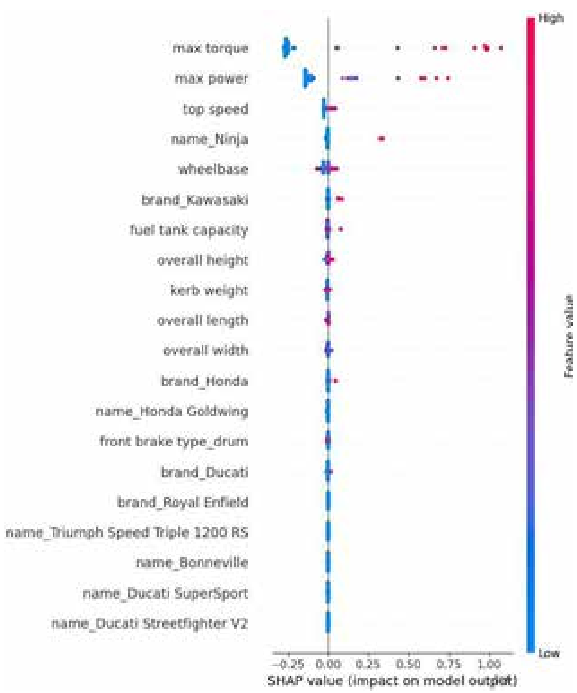


Fig. 8. Graph of SHAP Explanations

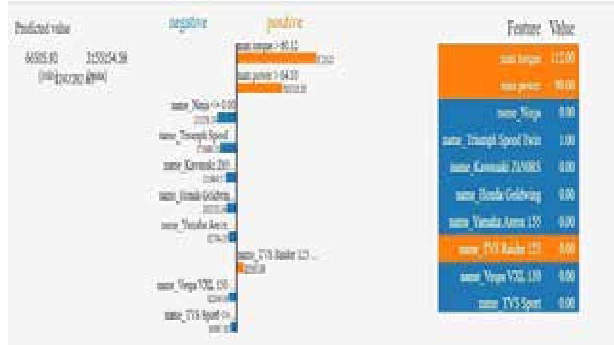


Fig. 9. Graph of LIME Explanations

DISCUSSION

The evaluation of the custom bike price prediction model, employing four regression algorithms, showed that, outperforming the other algorithms, the Random Forest Regressor algorithm achieved the highest accuracy score. This outcome signifies the suitability of the Random Forest Regressor algorithm for accurately predicting custom bike prices based on the provided features.

Moreover, the study emphasizes the significance of selected features such as brand, max power, max torque, fuel tank capacity, top speed, front brake type, kerb weight, overall length, overall width, wheelbase, and overall height in determining custom bike prices. The model effectively utilized these features to predict prices accurately, underscoring their substantial impact on the final price.

Despite these valuable insights, a limitation arises from the small dataset used, potentially impacting model performance. Future studies could enhance accuracy by employing a more extensive dataset. Additionally, augmenting features like engine type, suspension type, and exhaust type could further refine the model's precision.

Integrating Explainable AI (XAI), like feature importance plots or SHapley Additive exPlanations (SHAP), enhances interpretability and transparency in the model's decision-making process. This transparency aids stakeholders, including buyers and sellers, in understanding the contribution of selected features to predicted custom bike prices, fostering trust and informed decision-making in the custom bike market.

CONCLUSION

In conclusion, the study successfully employed machine learning techniques, including the Elastic Net, Adaptive Boosting, Decision Tree, and Random Forest regressions, to predict custom bike prices. The Random Forest Regressor exhibited superior accuracy, with an R-squared value of 0.89. This affirms the efficacy of machine learning in precisely estimating custom bike prices based on various features.

Moreover, the research highlighted the critical role of specific features in influencing custom bike prices, offering insightful information to both buyers and sellers. The integration of Explainable AI (XAI) methods enhanced transparency, enabling stakeholders to comprehend how selected features contribute to price predictions. Despite dataset limitations and potential biases, this study significantly advances our understanding of custom bike pricing dynamics and demonstrates the potential synergy between machine learning and XAI in this domain.

REFERENCES

1. Pudaruth, Sameerchand. (2014). Predicting the Price of Used Cars using Machine Learning Techniques. International Journal of Information & Computation Technology. 4. 753-764.
2. Xu, F., Uszkoreit, H., Du, Y., Fan, W., Zhao, D., Zhu, J. (2019). Explainable AI: A Brief Survey on History, Research Areas, Approaches and Challenges. In: Tang, J., Kan, MY., Zhao, D., Li, S., Zan, H. (eds) Natural Language Processing and Chinese Computing. NLPCC 2019. Lecture Notes in Computer Science(), vol 11839. Springer, Cham. https://doi.org/10.1007/978-3-030-32236-6_51
3. Bhagirath, Mittal, N., Kumar, S. (2021). Online Resale Bike Price Prediction in Indian Market. In: Singh, J., Kumar, S., Choudhury, U. (eds) Innovations in Cyber Physical Systems. Lecture Notes in Electrical Engineering, vol 788. Springer, Singapore. https://doi.org/10.1007/978-981-16-4149-7_13
4. Linardatos, P.; Papastefanopoulos, V.; Kotsiantis, S. Explainable AI: A Review of Machine Learning Interpretability Methods. Entropy 2021, 23, 18. https://doi.org/10.3390/e23010018
5. Gao, C., Chen, Y. (2022). Using Machine Learning Methods to Predict Demand for Bike Sharing. In: Stienmetz, J.L., Ferrer-Rosell, B., Massimo, D. (eds) Information and Communication Technologies in Tourism 2022. ENTER 2022. Springer, Cham. https://doi.org/10.1007/978-3-030-94751-4_25
6. Bukvić, L.; Pašagić Škrinjar, J.; Fratrović, T.; Abramović, B. Price Prediction and Classification of Used-Vehicles Using Supervised Machine Learning. Sustainability 2022, 14, 17034. https://doi.org/10.3390/su142417034
7. Carta, S., Podda, A.S., Reforgiato Recupero, D., Stanciu, M.M. (2022). Explainable AI for Financial Forecasting. In: Nicosia, G., et al. Machine Learning, Optimization, and Data Science. LOD 2021. Lecture Notes in Computer Science(), vol 13164. Springer, Cham. https://doi.org/10.1007/978-3-030-95470-3_5
8. S. Shaprapawad, P. Borugadda and N. Koshika, "Car Price Prediction:An Application of Machine Learning," 2023 International Conference on Inventive Computation Technologies (ICICT), Lalitpur, Nepal, 2023, pp. 242-248, doi: 10.1109/ICICT57646.2023.10134142.
9. Khade, O., Kadam, Y., Mahalle, P.N., Ingle, Y.S., Diwakar, M.P., Borade, M.R. (2023). "A Novel Software for Fruit Price Prediction Using Machine Learning". In: Fong, S., Dey, N., Joshi, A. (eds) ICT Analysis and Applications. ICT4SD 2023. Lecture Notes in Networks and Systems, vol 782. Springer, Singapore. https://doi.org/10.1007/978-981-99-6568-7_53.

Exploring Factors Influencing Job Placement Success Among College Students: A Data-Driven Analysis Using Machine Learning

Vinod.S.Agrawal*
MGM University
Aurangabad, Maharashtra
✉ vinodagrawal73@gmail.com

Sarika Shelke Kadam
MGM University
Dr. G. Y. Pathrikar College of Comp.Sci and IT,
Aurangabad, Maharashtra
✉ sarikashelke2032@gmail.com

ABSTRACT

Machine learning getting popular day by day, in every domain we can take the benefit of ML (Machine Learning) system. Machine learning models used for the prediction purpose. Here ML models are used to know the campus placement of student before student complete the degree. Like human learn from the past experiences, machine also can from historical records. These historical records called as Dataset. Here dataset collected from the open source repository called as Kaggle. Initially dataset is checked for the preprocessing like any null values, missing values, incorrect values, duplicate values which will affect on the final accuracy (performance).

Historical data contains placement records of alumni received from open source -kaggle. It includes information such as student academic achievements, internship, project, workshop, soft skill, extracurricular activities and placement outcomes. Through data preprocessing and feature engineering, we transform raw data into a structured format suitable for predictive modeling.

Prediction calculation taken using 06 different models. Machine learning model accuracy calculated in the form of precision, recall, f1-score and support.

KEYWORDS *: ML algorithms, SVM, Adaboost, XGboost, Naïve byes, Decision trees, Random Forest (RF), KNN, Logistic Regression(LR), Cross validation, predictive analysis.*

INTRODUCTION

Campus placement activity is very important part in student's college life. Aim of this research paper is to check the factors which are significant or influencing for the placement of the student. Machine will get trained using the given dataset and then it will able to tell the effect of various features on the job placement like internship, placement training.

Significance of the Study: In today's competitive job market, understanding the factors influencing job placement success among college students is crucial for both academic institutions and students themselves. By conducting a data-driven analysis using ML(machine learning) techniques, this research aims to uncover the underlying patterns and correlations within diverse datasets that traditional analytical methods may overlook. This study lies in its potential to provide actionable insights for improving job placement outcomes.

Objectives of the Study: The primary objective is to explore the factors influencing job placement success among college students through a data-driven approach by using machine learning techniques. Specifically, the objectives include: (1) Identifying key determinants of job placement success such as technical training, participation in innovative projects and internship experiences. (2) Developing predictive models capable of forecasting students' likelihood of securing employment opportunities.

Background of the Study: The transition from college to the company is a critical phase in the lives of young adults, with job placement success serving as a key determinant of future career prospects and financial stability. While various factors contribute to job placement success, including academic achievements, internship experiences, projects etc. Traditional analytical approaches often fall short in capturing the intricacies of this process due to their limitations in handling large and diverse datasets. This study proposes a data-driven analysis employing ML (machine learning) techniques to comprehensively explore the factors influencing job placement success among college students. By leveraging the power of ML(Machine Learning) algorithms, aim is to uncover hidden patterns, develop predictive models, and provide valuable insights to support efforts aimed at enhancing job placement outcomes for college graduates.

DEPENDENT AND INDEPENDENT VARIABLES

Independent variables in the dataset are 10th marks, 12th marks, 10th board, 12th board, stream,CGPA, internship, training, backlog, innovative project, communication, technical course. Dependent variable is job placement status.

Sample dataset

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Email	Name	Gender	10th boar	10th mark	12th boar	12th mark	Stream	Cgpa	Internship	Training(Y	Backlog in	Innovative	Communi	Technical	Placement(Y/N)?	
payal_roy	Payal Roy	Female	State Boar	96.7	CBSE	70.2	Mechanic	7.37	No	Yes	No	No	3	Yes	Not Placed	
shreyoshi	Shreyoshi	Female	WBBSE	96.2	WBCHSE	90.6	Electronic	9.35	No	No	No	Yes	4	No	Not Placed	
rohan_nai	Rohan Nai	Male	State Boar	97.5	CBSE	69.6	Informatic	7.84	No	Yes	No	Yes	3	Yes	Placed	
smita_aga	Smita Aga	Female	CBSE	96.9	Other stat	77.6	Computer	7.87	Yes	No	Yes	Yes	2	Yes	Not Placed	
samaira_s	Samaira S	Female	ICSE	99.1	CBSE	62.8	Computer	9.26	Yes	Yes	No	Yes	1	Yes	Not Placed	
rakeshdey	Rakesh De	Male	CBSE	85.5	CBSE	86	Computer	9.2	Yes	No	No	Yes	2	Yes	Not Placed	
dheeraj_t	Dheeraj Ti	Male	State Boar	98.2	CBSE	83.4	Computer	8.83	Yes	Yes	Yes	Yes	2	Yes	Not Placed	
dharmikc	Dharmik C	Male	State Boar	79.4	Diploma	82.1	Productio	7.52	Yes	No	No	Yes	3	Yes	Placed	
suman_se	Suman Se	Male	WBBSE	88	Other stat	83.2	Computer	7.06	No	No	No	Yes	3	Yes	Placed	
sneha_pal	Sneha Pal	Female	CBSE	84.3	CBSE	70.9	Civil Engir	7.34	No	No	No	No	3	Yes	Not Placed	
mukesh_r	Mukesh M	Male	ICSE	84.1	Other stat	67.9	Computer	7.12	No	No	Yes	No	1	No	Not Placed	
shreya_sh	Shreya Sh	Female	State Boar	97.8	ISE	95	Computer	8.87	Yes	Yes	No	Yes	4	Yes	Not Placed	
pranab_bl	Pranab Bh	Male	ICSE	83	CBSE	79.8	Computer	7.13	Yes	No	No	No	4	Yes	Not Placed	
mita_pal3	Mita Pal	Female	CBSE	78.5	Other stat	62	Mechanic	7.18	Yes	Yes	No	Yes	1	Yes	Placed	
kunal_bhc	Kunal Bho	Male	WBBSE	95.9	CBSE	73.2	Informatic	9.14	Yes	Yes	Yes	Yes	1	Yes	Not Placed	
amit_dey	Amit Dey	Male	WBBSE	75	Other stat	68.9	Electronic	7.58	No	No	No	Yes	4	Yes	Placed	
mita_barc	Mita Bard	Female	WBBSE	89.8	CBSE	88.6	Computer	7.66	Yes	Yes	No	Yes	5	Yes	Placed	
chatterjee	Naitik Cha	Male	ICSE	93.6	WBCHSE	87.6	Computer	8.92	Yes	No	No	No	3	No	Not Placed	
debanshu	Debanshu	Male	CBSE	87.4	ISE	80.2	Computer	7.17	Yes	Yes	No	No	4	Yes	Not Placed	
meyenka_	Meyenka	Female	WBBSE	96.3	CBSE	78	Electrical	7.51	No	Yes	No	Yes	1	Yes	Placed	
prakash_s	Prakash Si	Male	State Boar	82.4	Other stat	77.3	Mechanic	8.97	No	Yes	No	Yes	2	Yes	Placed	
nayanika_	Nayanika	Female	ICSE	87.6	ISE	88.9	Electrical	8.79	No	No	No	No	4	Yes	Not Placed	
ayush_kur	Ayush Kur	Male	ICSE	76.9	CBSE	68.2	Electrical	8.1	Yes	Yes	No	Yes	5	Yes	Placed	
rahul_yad	Rahul Yad	Male	ICSE	72.8	Other stat	87.2	Electrical	7.08	No	No	Yes	No	4	Yes	Not Placed	

Fig-1. DataSet having 401 Rows and 16 Columns

ARCHITECTURE DIAGRAM

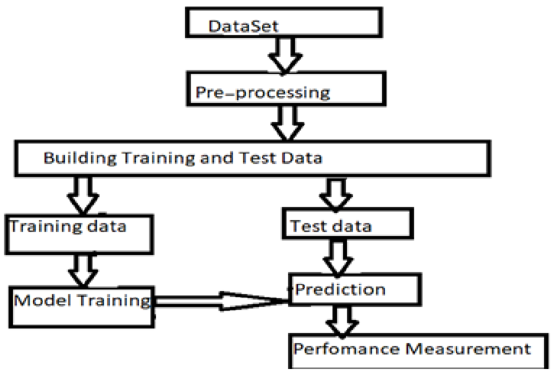


Fig.2: Architecture for Data Pre-processing, Model Training, Prediction and performance

Pre-processing is done on the dataset (null, invalid values, duplicate value, missing vale etc. removed). Dataset converted into training and test data. Algorithm accuracy calculated using confusion matrix.

METHODOLOGY

Population

Alumni data

Data Collection

Variables:

Dependent Variable: Placement Status(Binary: Yes/No)

Independent Variables: ssc_mark, hsc_mark, 10th board, 12th board, CGPA, internship, Training, Backlog, innovative project, communication, technical training, stream.

Data Analysis

Statistical Methods: Chi-square test for assessing the association between categorical variables.

Software

SPSS for statistical analysis, scikit-learn library using python for machine learning.

Procedure for Machine Learning

Algorithms: 06 ML models.

Data Preprocessing

Cleaning: Removal of outliers, Handling missing data ,Normalization/Scaling:

Training and Testing

80% of the records from dataset used for training, 20% of records used for testing.

Procedure for Statistical Analysis

Test Used: Chi-square

Significance Level:

$\alpha = 0.05$

RELATED WORKS

Irene Treesa Jose 1 , Daibin Raju2, et.al [1] made study on ML models to make the prediction. This research study makes the comparison of accuracy or say performance measurement. SVM provides Highest accuracy 100%.

T.Jeevalatha, N.Ananthi, D Saravana kumar[2] represented machine learning algorithms and shown the prediction. Accuracy of various ML models represented in the research paper. Highest accuracy 89.52% observed in ID3 and C4.5

Cherry D. Casuat, Enrique D. Festijo[3] represented ML models like DT(Decision Tree), RF (Random Forest) and SVM (Support Vector Machine). SVM algorithm accuracy found as 91%.

Shubham Khandale, Sachin Bhoite [4] represented machine learning(ML) algorithms and also worked on importance of each feature towards the campus placement of the student.

RESULT

The final result found using confusion matrix with different ML models as shown below in table.

Table 1: Performance measurement

Machine Learning Algorithm	Accuracy (K-Fold Cross Validation)
KNN	58.35
Support Vector Machine(SVM)	51.62
Decision Tree	89.28
Logistic Regression	88.28
Random Forest	89.52
Naïve Byes	79.56

Table-2 Classification Matrix

ML Model	Class	Precision	Recall	F1-score	Support
Decision Tree	0	0.86	0.80	0.83	40
	1	0.82	0.88	0.85	41
Logistic Regression	0	0.94	0.82	0.88	40
	1	0.85	0.95	0.90	41
Support Vector Machine (SVM)	0	0.49	0.97	0.65	40
	1	0.50	0.02	0.05	41
Naïve Byes	0	0.90	0.45	0.6	40
	1	0.64	0.95	0.76	41
K Nearest Neighbors (KNN)	0	0.59	0.55	0.57	40
	1	0.59	0.63	0.61	41
Random Forest	0	0.94	0.82	0.88	40
	1	0.85	0.95	0.9	41

HYPOTHESES TESTING:

Hypothesis 1:- Random Forest is the best suitable algorithm for prediction.

Null Hypothesis:- Random Forest is not the best suitable algorithm for prediction.

Alternate Hypothesis: Random Forest is the best suitable algorithm for prediction.

From Table-1 it is found that the Random Forest model gives highest accuracy which rejects the alternate hypothesis and accept the null hypothesis. Random Forest algorithm showed highest accuracy.

Hypothesis 2: Technical Training Enhances Students' Job Placement Prospects

Null Hypothesis: Technical Training does not enhance students' job placement prospects.

Alternative Hypothesis: Technical Training does enhance students' job placement prospects.

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	405.400[a]	4	.000
Likelihood Ratio	17.387	4	.002
N of Valid Cases	402		

Fig-3 Chi square test on Technical training and job placement

To prove above hypothesis, Chi –squared test applied in which significance value (p-value) received as 0.000 (shown in Fig-3) means accepts the alternate hypothesis.

Hypothesis 3: Participation in innovative projects positively correlates with placement success.

Null Hypothesis: Participation in innovative projects negatively correlates with placement success.

Alternative Hypothesis: Participation in innovative projects positively correlates with placement success.

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	532.356[a]	6	.000
Likelihood Ratio	173.606	6	.000
N of Valid Cases	402		

Fig 4 Chi square test on Innovative project and job placement

To prove above hypothesis, Chi –squared test applied in which significance (p-value) received as 0.000 (shown in Fig-4) means accepts the alternate hypothesis.

Hypothesis 4: Internship experiences increase the likelihood of securing placements

Null Hypothesis: Internship experiences do not increase the likelihood of securing placements.

Alternative Hypothesis: Internship experiences do increase the likelihood of securing placements.

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	402.110[a]	4	.000
Likelihood Ratio	14.100	4	.007
N of Valid Cases	402		

Fig-5 Chi square test on Innovative project and job placement

To prove above hypothesis, Chi –squared test applied in which significance (p-value) received as 0.000 (shown in Fig-5) means accepts the alternate hypothesis.

9. Conclusion:

Prediction of likelihood of placement of student is possible shown in Table-1 based on the various academic features. Accuracy comparison is represented in Table-1. Random Forest algorithm gives highest accuracy as 89.52 %.The accuracy may differ for different dataset. Accuracy is also calculated in the form of precision, recall, f1-score and support shown in Table-2.The findings underscored the multifaceted nature of job placement success, with factors such as internship experiences and technical training demonstrating significant positive correlations. K-fold techniques give the mean of different accuracy of models. These factors like internship, project, technical training work together in many ways, and understanding them can help colleges for better student placements. By using data and technology like machine learning, we can make predictions for student placement.

REFERENCES

1. Irene Treesa Jose 1 , Daibin Raju2, et.al , "Placement Prediction using Various Machine Learning models and their Efficiency Comparison" , International Journal of Innovative Science and Research Technology, Volume 5, Issue 5, May – 2020
2. T.Jeevalatha, N.Ananthi, D Saravana kumar, "Performance Analysis of Undergraduate Students Placement Selection using Decision Tree Algorithms", International Journal of Computer Applications (0975 – 8887) Volume 108 – No 15, December 2014
3. Cherry D. Casuat, Enrique D. Festijo, "Predicting Students' Employability using Machine Learning Approach", 2019 6th IEEE International Conference on Engineering Technologies and Applied Sciences (ICETAS)
4. Shubham Khandale, Sachin Bhoite, "Campus Placement Analyzer: Using Supervised Machine Learning Algorithms", International Journal of Computer Applications Technology and Research Volume 8–Issue 09, 358-362, 2019, ISSN:-2319–8656.

Case Study on Machine Learning Algorithms

S. P. Sakpal, Sanjay Gawali
Department of Computer Engineering
G.M. Vedak Institute of Technology
Raigad, Maharashtra
✉ snehalmor@gmvit.com
✉ sanjaygawali72@gmail.com

T D Bhatt
CMR College of Engineering & Technology
Hyderabad, Telangana

Gajanan P Khapre
Department of Electronics & Computer Engineering,
VPM's MPCOE
Velneshwar, Maharashtra
✉ gajanan.khapre@vpmmpcoe.org

M. A. Mohite
Department of ENTC
Gharda Institute of Technology
Lavel

ABSTRACT

The scientific study of the statistical models and techniques that computer systems employ to complete tasks without explicit programming is known as machine learning, or ML for short. being aware of algorithms for many frequent applications. One of the reasons why a computerized search engine like Google works so effectively every time it is used to look for information is that it uses an algorithm that is continually learning how to rank web pages. These algorithms are used in a variety of applications, including statistical analysis, image processing, mining data, and more. The major advantage of deep learning is that methods may function autonomously after they have determined whatever to do with the information. This paper gives a brief summary and prognosis for the wide range of uses for ML algorithms has been

KEYWORDS *: Reinforcement learning, supervised learning, unsupervised learning, machine learning, algorithms, and pseudo code.*

INTRODUCTION

Humans have utilized several instruments from the start of time to execute various tasks more swiftly and easily. Many machines have been developed solely because of human inventiveness. By enabling individuals to satisfy a variety of requirements, such as computing, travel, and industry, these innovations have made life easier for humans. And among them all is the use of machine learning [1,2, 4, 5, 7].

Supervised Learning

Supervised learning in deep learning entails learning a function that translates inputs into results using labeled training data. It uses instances of input-output pairs to infer this function, and algorithms need supervision to learn successfully. The dataset is usually partitioned into training and testing subsets, with the objective of predicting or categorizing output variables. Because of the number of information accessible, machine learning has grown more important in a variety of industries [5-6]. It seeks to extract information from data using techniques devised by programmers and mathematicians, allowing computers to learn without explicit instruction.

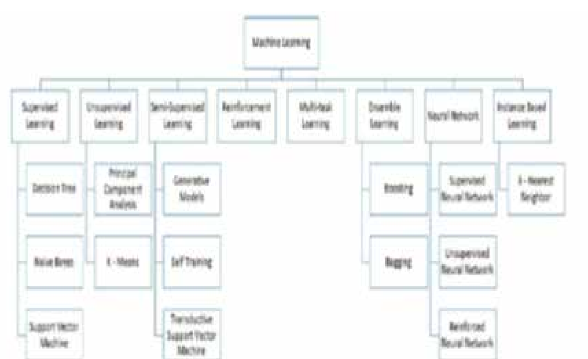


Fig. 1 Block diagram of Machine learning techniques

Discover patterns in the initial dataset and utilize them to forecast or categorize information from the test data. The approach for supervised deep learning algorithms is illustrated in the image below. This article has discussed some of the most popular supervised machine learning algorithms. [7, 8]

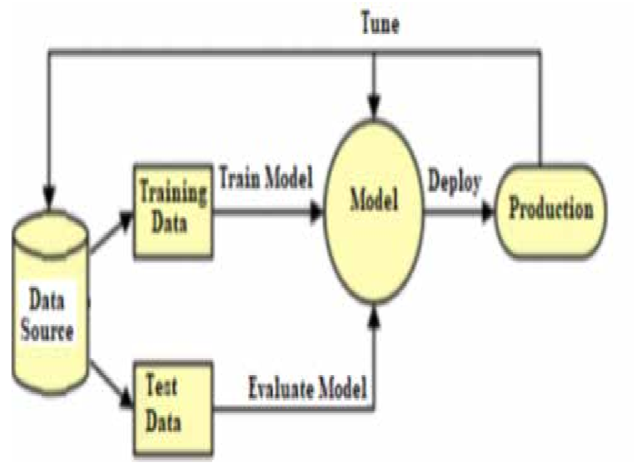


Figure 2: Supervised learning Workflow

Decision Tree

A decision tree is a chart that shows the decisions made and the outcomes they produce as a tree. The points on the graph denote a choice or action, while the edges provide the criteria or guidelines for making decisions. There are nodes and branches in every tree. Each branch provides an approximation of the node's value, and each node indicates a group property that needs to be classified [1,3]..

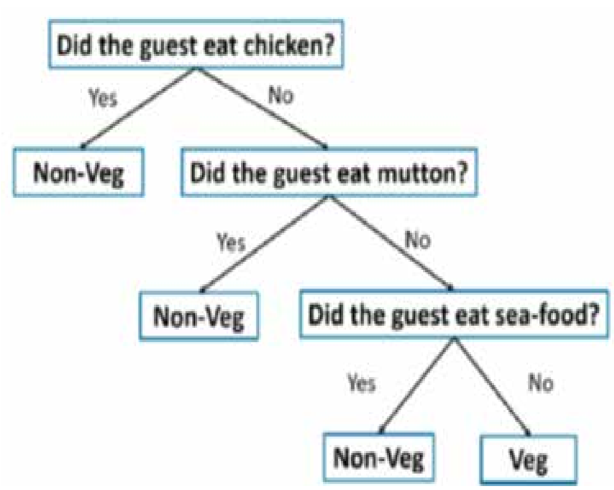


Figure 3: Decision Tree

Navie Bayes

It is a categorization approach that uses the Bayes Theorem and assumes predictor independence. In easy-to-understand terms, "a naive Bayes classification algorithm maintains a guess that a characteristic's presence within a class exists regardless of its existence of any other feature" . Naive Bayes' major industrial focus is text classification. Cluster and categorizing are its principal applications, and they are based on the conditional likelihood of a certain event happening [2, 7].

Support Vector Machine

Support Vector Machines is another famous cutting-edge machine learning approach. SVM are supervised learning models that assess data for regression and classification, as well as the accompanying learning methods. SVMs may successfully perform both linear and non-linear classification by implicitly converting their inputs into feature spaces that are highly dimensional. This approach is referred to as the "the kernel trick." In essence, it establishes boundaries between different classes. The classification error is reduced by designing the margins to optimize the space between them as well as the classes [4].

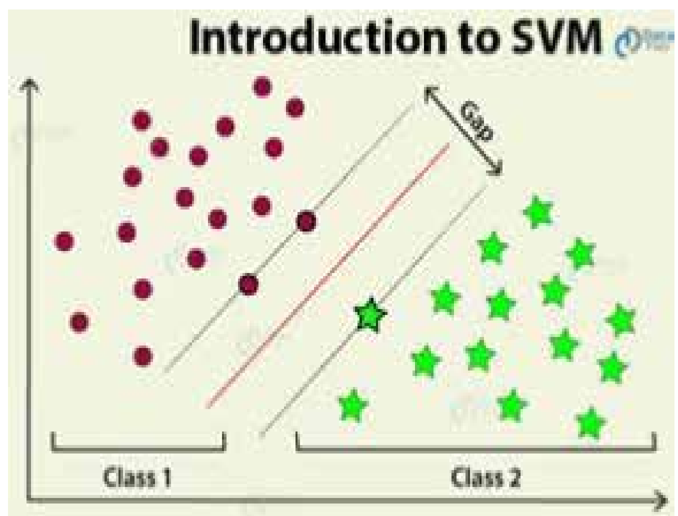


Figure 4: Support Vector Machine

Unsupervised Learning

Unsupervised learning is referred termed as such because, unlike supervised learning, there aren't any right or incorrect replies. The algorithms are responsible for discovering and displaying the intriguing structure in the data. The data has few features that unsupervised learning systems can extract. When new data is added, it detects the type of data using the features this has already learnt. Feature reduction and clustering are its primary applications [4-6].

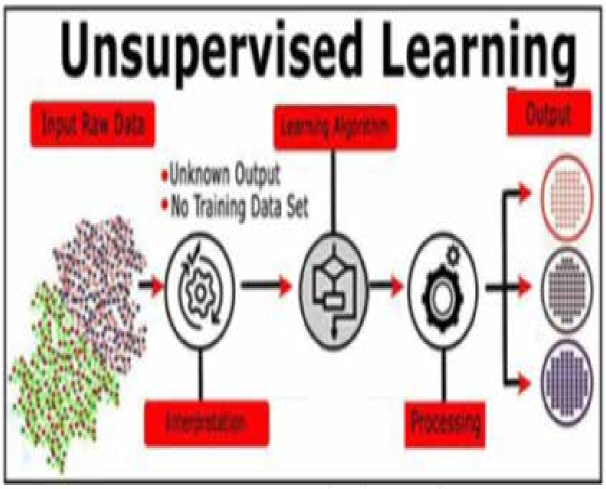


Figure 5: Unsupervised Learning

Principal Component Analysis

A collection of observations of possibly associated variables are converted into a set of values of entirely separate variables, or principle elements, using an orthogonal change in the statistical method known as principal component analysis." To enable and speed up calculations, the data dimension is reduced in this manner. It demonstrates an array of variables' variance-covariance structure using linear combinations. It is widely used as a dimensionality reduction technique. [1]

Connecting each location in the data set in question to the closest center is the next step. The first step is finished and a young group age is attained when there are no more points. We now need to compute k new the center [5], as the Barry centres are the clusters generated by the preceding step.

Reinforcement Learning

Machine learning, also known as reinforcement programming, is the study of how agents in software should act in a certain scenario to optimize a notion termed cumulative reward. One of the three key paradigm in machine learning is reinforcement learning, along with supervised instruction and unsupervised teaching. [6]

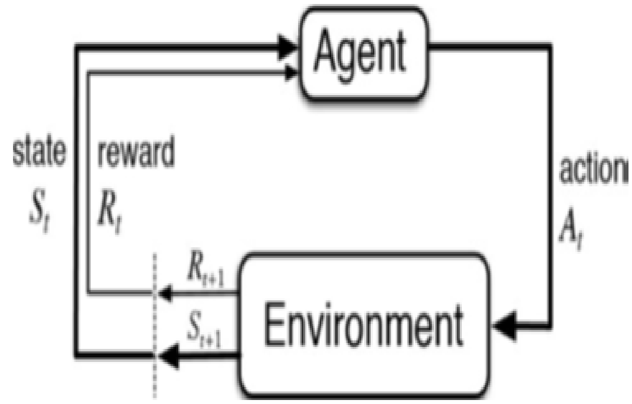


Figure 7: Reinforcement Learning

Neural Networks

A neural network, whether artificial or organic, comprises algorithms designed to emulate human brain functionality, revealing underlying correlations in data. Originating from machine learning, neural networks are increasingly utilized in trading system development due to their ability to adapt to changing input and deliver optimal outcomes without modifying output criteria. These networks operate across three levels: the input layer receives data, the hidden layer processes it, and the output layer transmits computed results [3, 7, 8]

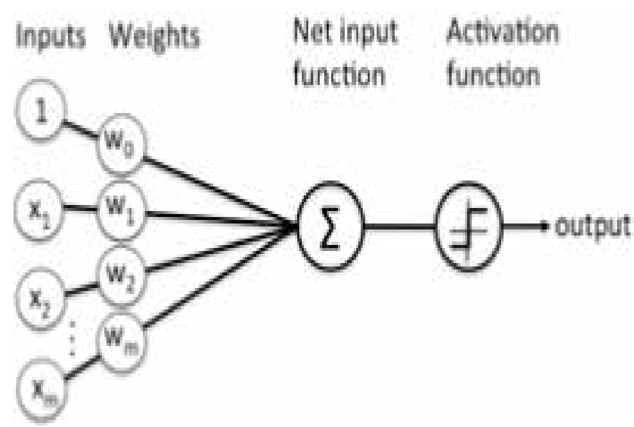


Figure 8 : Neural Networks

K-Nearest Neighbor

The "k-nearest neighbors (KNN)" technique is a basic supervised machine learning approach that may be used to solve regression and classification problems simultaneously. The main disadvantage is that, while it is easy to use and understand, it gets substantially slower as the number of data handled increases [2,4].

CONCLUSION

Machine learning can be done either supervised or unsupervised. Choose Supervised Learning if you have insufficient knowledge for training that is accurately marked. Unsupervised learning is typically more effective and produces better outcomes with larger data sets. If you have a significant amount of data, employ deep learning techniques. You also have expertise of deep reinforced learning and reinforcement learning. You now understand the concept, applications, and limits of neural networks. The paper provides an overview of machine learning algorithms. Whether they know it or not, everyone now employs machine learning. From displaying photographs on social media platforms to obtaining product suggestions when shopping online. A overview of the majority of commonly used algorithms in machine learning is provided in this release.

REFERENCES

1. W. Richert, L. P. Coelho, "Building Machine Learning Systems with Python", Packt Publishing Ltd., ISBN 978-1-78216-140-0
2. J. M. Keller, M. R. Gray, J. A. Givens Jr., "A Fuzzy K-Nearest Neighbor Algorithm", IEEE Transactions on Systems, Man and Cybernetics, Vol. SMC-15, No. 4, August 1985
3. https://www.geeksforgeeks.org/machine-learning/
4. S. Marsland, Machine learning: an algorithmic perspective. CRC press, 2015.
5. M. Bkassiny, Y. Li, and S. K. Jayaweera, "A survey on machine learning techniques in cognitive radios," IEEE Communications Surveys & Tutorials, vol. 15, no. 3, pp. 1136–1159, Oct. 2012.
6. https://en.wikipedia.org/wiki/Instance-based_learning
7. R. S. Sutton, "Introduction: The Challenge of Reinforcement Learning", Machine Learning, 8, Page 225-227, Kluwer Academic Publishers, Boston, 1992.
8. P. Harrington, "Machine Learning in action", Manning Publications Co., Shelter Island, New York, 2012.

Intention Mining for Polarity Temperament Using Generative Pre-Trained Transformer 2 for News Blog

Varsha D. Jadhav*
Gitanjali B. Yadav
Vishwakarma Institute of Information Technology
Pune, Maharashtra
✉ drvarshajadhav22@gmail.com

Dhananjay R. Dolas
List Jawaharlal Nehru Engineering College
MGM University
Aurangabad, Maharashtra
✉ drdolasjnec@gmail.com

ABSTRACT

In this day of endless information and never-ending news streams, blogs provide dynamic platforms for real-time updates on breaking news. This research study uses the commanding language model GPT-2 (Generative Pre-trained Transformer 2) to provide a novel approach for intention mining analysis for live news blogging. By attaching the contextual thought and language generation skills of GPT-2, the structure purposes to offer a perceptive and nuanced analysis of intentions articulated in user remarks and ponderings within live news blog posts. A dataset containing news-related content and corresponding intentions for polarity temperament will be used to fine-tune the GPT-2 model as part of the intended methodology. Decision-makers can benefit greatly from the real-time intention mining for live news blogging, which also has great promise for improving user experience and supporting journalists.

KEYWORDS : *Intention mining, GPT-2, News blog, Self-attention, GPT-2 tokenizer, Pipeline.*

INTRODUCTION

There is enormous amount of data on the news blogs related to a country, world, sports, science and technology, entertainment and opinion. This data can be used to mine the intentions. There is no appropriate definition of intention. The authors [1] have defined intention in terms of polarity and emotions. The three types of intentions based on their emotional orientation are positive, negative, and neutral. The emotion intentions are anger, disgust, fear, happy, sad, etc. The traditional lifestyle in several domains has reshaped the modern technological era. With advancement of information technology, publishing news and events has become very fast in the form of comments, blogs, social media, etc. [2]. Manually processing the data is a challenging task. News blogs consists of polarity temperament such as positive intention and negative intension [3,4].

Traditional machine learning models are extensively used for text analysis with good results because they are more understandable [5]. They are more computationally effective especially on smaller datasets. Traditional machine learning models fight to understand the background in natural language which mark the performance on complex polarity intension tasks [6]. GPT-2 captures complex contextual relations in language understanding. It can be fine-tuned on smaller datasets for specific polarity intension tasks. GPT-2 automatically learn appropriate features from data, thus dropping manual feature engineering [7]. There are no one-size fits, and the choice among machine learning and GPT-2 depends on specific requirements, available resources and the nature of intension analysis. The research is based on generative pre-transformer – 2 methods for polarity temperament intention mining of news articles.

LITERATURE SURVEY

Today, the main focus is on natural language understanding tasks. A brief literature survey is carried to analyse text data. Unsupervised pre-training has revolutionized natural language processing. The effectiveness of utilizing pre-trained checkpoints in sequence generation has been illustrated [8]. A sequence model based on the transformer architecture was created to be compatible with publicly accessible pre-trained BERT, GPT-2, and RoBERTa checkpoints. This model underwent a thorough empirical investigation, exploring the usage of both the encoder and decoder components with the specified checkpoint. The model produces outcomes in tasks such as machine translation, text summarization, as well as sentence splitting and fusion. The study delves into examining the effectiveness and responsiveness of neural architectures derived from pre-existing GPT-2 and BERT models [9]. Adjusting the performance of fine-tuning in BERT can be highly sensitive to variations in freezing transformer layers, batch size, and learning parameters. This sensitivity to stochasticity makes the fine-tuning process more volatile compared to GPT-2, where stability is generally higher. The initial layers of both GPT-2 and BERT store crucial word pattern details that need to be preserved. The goal of generative models is to simulate the joint distribution of all pertinent data using parameters that may be seen as representing latent structures or characteristics in the data. The latent structures are disclosed by fitting such a model to the observed data and obtaining an estimate of these parameters. Latent topic analysis in text data has previously made extensive use of these models. Sentiment analysis at the topic level is now possible thanks to the extension of several of the models to include both subjects and sentiment. Furthermore, in order to facilitate a deeper examination of sentiment and opinions, new generative models have been built to model both opinionated text data and their associated numerical sentiment ratings [10]. These models allow for the extraction of latent relative weights on various subtopics in addition to subtopic-level sentiment. These generative models require little to no human labour for model estimate, yet they are robust and general. As a result, they are widely applicable for doing opinion mining and sentiment analysis on any type of text data in any natural language. Generative AI is a computational technique capable of generating new and meaningful content related to text, images, or audio from training data. The authors [11] have provided a conceptualization of generative AI as socio-technical system using examples such as Dall-E2, GPT-4 and Copilot. A plan for Business and Information Systems Engineering (BISE) research is conferred for its openings and challenges.

METHODOLOGY

Generative pre-transformer 2 (GPT-2) involve the architecture of the model, the training process, and the specific components like GPT2LMHeadModel, GPT2Tokenizer, and pipeline.

GPT-2 Architecture

The GPT-2 model is based on the transformer architecture which includes sell-attention mechanisms [13]. The forward pass involves processing input tokens through multiple layers of attention and feedforward layers [14]. The output is a probability distribution over the vocabulary for each position in the input sequence.

$$Z^{l} = \text{Attention}^{l}\ (X) + X \tag{1}$$

$$A^{l} = \text{Layer Norm}\ (Z^{l}) \tag{2}$$

$$Z^{‘(l)} = \text{Feed forward}^{l}\ (A^{(l)}) + A^{(l)} \tag{3}$$

$$A^{‘(l)} = \text{Layer Norm}\ (Z^{’(l)}) \tag{4}$$

Where, X is the input sequence, Attention^{l} is the self - attention mechanism,

Feedforward^{l} is the feedforward layer, and

LayerNorm is the layer normalization

The self-attention mechanism

The acceptance of the Transformer model in natural language processing (NLP) tasks branches from its actual ability to competently capture wide contextual relations within orders. The self-attention mechanism allows the model to measure the importance of specific words within a order in relation to one another [14]. It is used for processing input sequence where the relations among elements are not fixed and may rely on the context. Given an input sequence, each word is rooted into a vector illustration. The input vector is denoted as a matrix, where each row resembles to the embedding of a word. The self-attention mechanism introduces 3 vectors for each word, The vectors are linear estimates of the novel word embeddings. It is represented as query (q), key(k) and value(v).

By taking the dot product of the respective query and key vectors, the score for the relation among that query and another key is computed. The dot product is normalized by dividing it by the square root of the dimension of the key vectors to alleviate the gradients. [15].

$$Score(q_i, k_j) = \frac{q_i \cdot k_j}{\sqrt{d_k}} \quad (5)$$

Where qi is the query vector for word i, kj is the key vector for word j, and dk is the dimensionality of the key vectors.

The computed scores are passed through a softmax function to obtain normalized attention weights. The softmax function ensures that the weights sum up to 1, making them suitable as probabilities.

$$Attention\ (q_i, k_j) = \frac{\exp(Score(q_i, k_j))}{\sum_{j'} \exp(Score(q_i, k_{j'}))} \quad (6)$$

The attention weights represent the importance of other words relative to the current word. Finally, weighted sum of the value vectors using attention weight is used to get the attention mechanism.

$$Attention\ Mechanism(q_i, k, v) = \sum_j Attention(q_i, k_j) \cdot v_i \quad (7)$$

The Feedforward layer

It is a critical building block in neural network architecture and acts to play central role in allowing like the network to learn and signify intricate functions [16]. In the context of the transformer architecture, feedforward layers are used in the encoder and encoder blocks to process and transform the input sequence.

LayerNorm is a normalization technique used in neural networks to normalize the activations within a layer. The helps stabilize and speed up the training of neural networks by normalizing the input to a layer across its features.

Given in input vector X=[x_1,x_2,----,x_n] for a layer, LayerNorm computes the mean (μ) and the standard deviation (σ) of the values across the features and normalized each feature independently [17].

$$Mean(\mu) = \frac{1}{n}\sum_{i=1}^{n} x_i \quad (8)$$

$$Standard\ Deviation\ (\sigma) = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \mu)^2} \quad (9)$$

$$Normalization\ \hat{x_i} = \frac{x_i - \mu}{\sigma + \varepsilon} \quad (10)$$

Here, ε is a small constant added for numerical stability. The scale and shift parameters in batch normalization is given as

$$y_i = \gamma \hat{x_i} + \beta \quad (11)$$

Where, γ and β are learnable parameter.

Given an input vector X, the LayerNorm operation is defined as

$$LayerNorm(X) = \gamma \odot \frac{X - \mu}{\sigma + \epsilon} + \beta \quad (12)$$

Where ʘ denotes element-wise multiplication μ and σ are mean and standard deviation across the features of X. γ and β are learnable scale and shift parameters respectively.

GPT 2 – Tokenizer

It is responsible for converting input text into numerical tokens which are fed into GPT-2 model [18]. It tokenizes the input text into sub-words or words, and each token is assigned a unique numerical index. It treats spaces like parts of tokens so that the word is encoded differently irrespective of whether it is at beginning of the sentence or not. The tokenizer sustains a language that plans tokens to their equivalent indices.

Pipeline

The Hugging Face library provides a high-level API pipeline. In the situation of GPT2 and sentiment analysis, the pipeline generates text. This procedure comprises of encoding the input text into tokens using the tokenizer and feeding these tokens into the GPT-2 model for text generation. Text is decrypted back into human-readable form.

The complete process of text prediction and classification for sentiment analysis is shown in the block diagram figure 1.

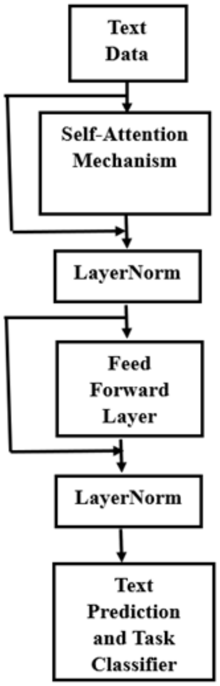


Fig. 1. Block diagram of GPT-2 Text Classifier

DATA COLLECTION

Data was collected from mews.abplive.com for a week from 13th December 2023 to 19th December 2023. The news related to India, sports, entertainment, science, technology and opinion was retrieved. BeautifulSoup library of python parsed the HTML content of the page. The data was retrieved and stored to text file. The text file is then converted into .csv file. The csv file enables easy assigning of intention to each sentence.

RESULTS AND DISCUSSION

News blogs express temperament related to the recent events. The data retrieved from ABP live news consists of entities such as India news, sports, entertainment, science, technology, opinion. The generative pre-trained transformer model assigns intention scores to each retrieved news and also the polarity temperament indicating whether it is positive or negative. The total number of news related to each entity and the intention polarity temperament varies each day. The intention scores indicate the higher chances of polarity temperament. For example, the sports news retrieved," World Cup 2023: who will be the best and effective bowlers from team India | Ind vs NZ" is aligned the intention score 0.970529 with positive polarity temperament. The news, "World Cup Semi Finals: What will be Tean India's strategy for bowling? | Ind Vs NZ" is assigned the intention score 0.99568 with negative polarity temperament. Its means that there is 97.05 % of high chances of the news being positive and 99.5% higher chances of the news being negative.

The total number of news related to entities such as news India, sports, entertainment, science, technology, opinion collected each day from 13th December 2023 to 19th December 2023 with intention polarity temperament is shown in table 1.

Table 1 Number of Intention Polarity Temperament Retrieved each day

Dates	13-12-2023		14-12-2023		15-12-2023		16-12-2023		17-12-2023		18-12-2023		19-12-2023	
Intention Polarity Temperament	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative
India	8	11	5	15	4	16	4	13	6	13	19	13	4	16
Sports	8	9	9	8	8	9	8	10	7	10	6	11	6	11
Entertainment	10	6	7	10	7	9	7	9	7	9	8	8	8	8
Science	12	8	10	10	9	11	9	11	10	10	9	11	9	11
Technology	9	10	8	11	6	13	6	13	7	12	5	14	5	14
Opinion	8	8	6	11	7	9	6	11	7	10	3	14	3	14

Table 2. Overall total number of intention polarity Temperament for each entity. And figure 1 shows the graphically.

Table 2 Overall total number of intention polarity Temperament for each entity

Entities	Intention Polarity Temperament	Overall Total
India	Positive	50
	Negative	97
Sports	Positive	52
	Negative	68
Entertainment	Positive	54
	Negative	59
Science	Positive	68
	Negative	72
Technology	Positive	46
	Negative	87
Opinion	Positive	40
	Negative	77

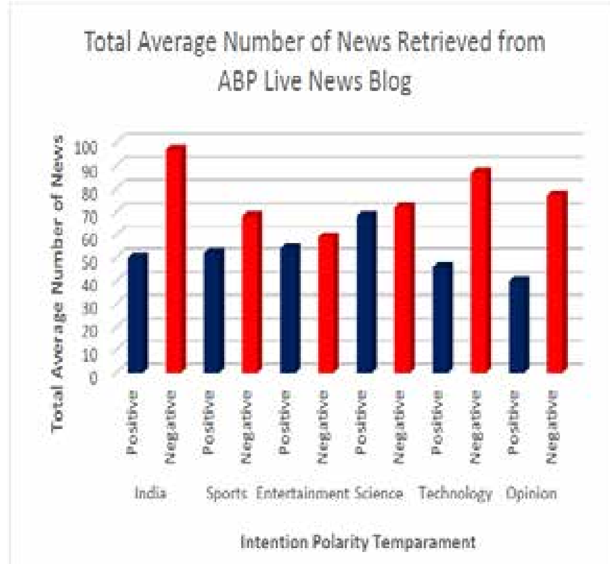


Fig. 2 Total Average Number of News retrieved from ABP Live News Blog

Table 3 shows the polarity intension scores for each day

Dates	13-12-2023		14-12-2023		15-12-2023		16-12-2023		17-12-2023		18-12-2023		19-12-2023	
Intention Polarity Temperament	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative
India	0.9316	0.9807	0.95088	0.9387	0.8945	0.959	0.9461	0.9837	0.9191	0.9536	0.9826	0.8839	0.9773	0.9173
Sports	0.9106	0.9774	0.9686	0.9518	0.9421	0.968	0.9702	0.9819	0.9067	0.9337	0.9625	0.8873	0.9625	0.8873
Entertainment	0.9019	0.9766	0.9883	0.947	0.9693	0.953	0.9942	0.94	0.9349	0.9357	0.9962	0.8491	0.9962	0.8491
Science	0.9093	0.9662	0.95105	0.9464	0.9371	0.96	0.9462	0.97	0.9084	0.9306	0.9459	0.8762	0.9459	0.8721
Technology	0.9079	0.9662	0.97107	0.9472	0.9707	0.958	0.9843	0.9667	0.9248	0.9335	0.9808	0.8294	0.9808	0.8929
Opinion	0.9227	0.9817	0.99211	0.9456	0.9548	0.916	0.9922	0.9817	0.9349	0.9407	0.9952	0.9057	0.9952	0.9057

Table 4 shows the Average intention score for the polarity temperament and figure 2 shows it graphical representation.

Table 4. Average Intention Score for Polarity Temperament

Entities	Intention polarity Temperament	Average Intention Score
India	Positive	0.9432
	Negative	0.9453
Sports	Positive	0.9462
	Negative	0.9411
Entertainment	Positive	0.9687
	Negative	0.9214
Science	Positive	0.9348
	Negative	0.9317
Technology	Positive	0.96
	Negative	0.9277
Opinion	Positive	0.9696
	Negative	0.9395

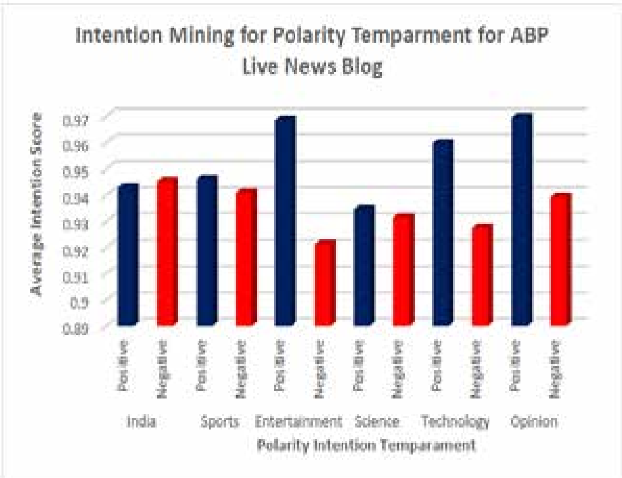


Fig. 3 Intention Mining for Polarity Temperament for ABP Live News Blog

When figure 1 and figure 2 are compared, it is observed that the total average number of news for negative temperament is more than that of positive. Also, the intention polarity score for the negative is high than positive as compared to negative. It is analysed that the news related to the entity India is negative with higher chances. It is so because, if the government and people are made aware of negative news than quick actions can be provided so as to overcome the situations. For example, the news, "Floods Bring Tamil Nadu To Its Knees As Heavy Rains Continue To Batter State," is identified as negative polarity temperament with high chance of 98.82%. Here quick remedies can be applied to rescue people, which really helps.

For the entity's sports, entertainment, science, technology, and opinion the total number of negative polarity intention temperament are more than positive But, the intention score for positive polarity temperament is higher than negative. It can be analysed that sports, entertainment, science, technology, and opinion are more support be news article so as to encourage people.

CONCLUSIONS

The total number of intention polarity temperament news retrieved from ABP line news blog as seen from figure 1 is that the negative intention polarity temperament is more than that of positive. Whereas, the average intention score for polarity temperament as in figure 2 is analysed that for news related to India negative intention polarity temperament is higher than positive. For a particular event related to India news, if there is criticism than the government take a closer look and tries to make improvements for the societal benefit. For the news related to sports, entertainment, science, technology and opinion, positive intention polarity temperament is high as compared to negative. This can be analysed that people are encouraged in these fields to participate in more numbers and bring glory to the country. Intention mining can be a powerful tool for news blogs to enhance content strategy, engage with the audience effectively, and maintain a positive brand image.

Also, generative pre-trained transformer-2 is a language-based model and has several advantages. It has contextual understanding of words over the complete sentence. Fine-tuning using smaller datasets is more effective due to pre-training. During the pre-training process it automatically relevant features. As intentions is not having any specific definition, the next step is to define emotion in terms of emotions. Also, the hidden intentions need to analysed using ontologies.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author(s) used CHATGPT in order to improve language and readability. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

REFERENCES

1. Varsha D. Jadhav, et al. (2023). An Intensive Spectrum for Intention Mining Analysis. International Journal on Recent and Innovation Trends in Computing and Communication, 11(10), 83–90. https://doi.org/10.17762/ijritcc.v11i10.8468
2. A. Kohut, C. Doherty, M. Dimock and S. Keeter, Americans spending more time following the news. Pew Research Center, 2010.
3. N. Godbole, M. Srinivasaiah, and S. Sekine, Large-scale sentiment analysis for news and blogs. In International Conference on Weblogs and Social Media, Denver, CO, 2007.
4. J. Lei, Y. Rao, Q. Li, X. Quan, and L. Wenyin, "Towards building a social emotion detection system for online

news," Future Generation Computer Systems, vol. 37, pp. 438–448, 2014.

5. F. Lagrari, Y. Elkettani "Traditional and Deep Learning Approaches for Sentiment Analysis: A Survey", Advances in Science, Technology and Engineering Systems Journal, vol. 6, no. 4, pp. 1-7 (2021).

6. M. . Sanwal and M. M. . Mazhar, "Performance Comparison of Machine Learning and Deep Learning Models for Sentiment Analysis of Hotel Reviews", IJITAS, vol. 5, no. 1, pp. 01–07, Aug. 2023.

7. Kaur, G., Sharma, A. A deep learning-based model using hybrid feature extraction approach for consumer sentiment analysis. J Big Data 10, 5 (2023). https://doi.org/10.1186/s40537-022-00680-6

8. Sascha Rothe, Shashi Narayan, Aliaksei Severyn; Leveraging Pre-trained Checkpoints for Sequence Generation Tasks. Transactions of the Association for Computational Linguistics 2020; 8 264–280. doi: https://doi.org/10.1162/tacl_a_00313

9. Qian, Tracy & Xie, Andy & Bruckmann, Camille. (2022). Sensitivity Analysis on Transferred Neural Architectures of BERT and GPT-2 for Financial Sentiment Analysis. 10.48550/arXiv.2207.03037.

10. Wang, Hongning & Zhai, ChengXiang. (2017). Generative Models for Sentiment Analysis and Opinion Mining. 10.1007/978-3-319-55394-8_6.

11. Feuerriegel, Stefan & Hartmann, Jochen & Janiesch, Christian & Zschech, Patrick. (2023). Generative AI.

12. Bartoli, Alberto & Medvet, Eric. (2020). Exploring the Potential of GPT-2 for Generating Fake Reviews of Research Papers. 10.3233/FAIA200717.

13. Lee M. A Mathematical Interpretation of Autoregressive Generative Pre-Trained Transformer and Self-Supervised Learning. Mathematics. 2023; 11(11):2451. https://doi.org/10.3390/math11112451

14. Vig, Jesse & Belinkov, Yonatan. (2019). Analyzing the Structure of Attention in a Transformer Language Model. 63-76. 10.18653/v1/W19-4808.

15. Islam, Saidul & Elmekki, Hanae & Elsebai, Ahmed & Bentahar, Jamal & Drawel, Nagat & Rjoub, Gaith & Pedrycz, Witold. (2023). A Comprehensive Survey on Applications of Transformers for Deep Learning Tasks.

16. Bashath, Samar & Perera, Nadeesha & Tripathi, Shailesh & Manjang, Kalifa & Dehmer, Matthias & Emmert-Streib, Frank. (2021). A data-centric review of deep transfer learning with applications to text data. Information Sciences. 585. 10.1016/j.ins.2021.11.061.

17. Wang, Zhiqiang & She, Qingyun & Zhang, PengTao & Zhang, Junlin. (2020). Correct Normalization Matters: Understanding the Effect of Normalization On Deep Neural Network Models For Click-Through Rate Prediction.

18. Jayasurya, Puppala & Ganta, Swetha & Damerla, Uday & Mandha, Hemanth & Mohan, Gandikota. (2023). Tokenization in GPT Models: Overcoming Challenges for Non-English Languages. 12. 24-30.

19. Oosherian, Mina & Purwins, Hendrik & Rathnayake, Purna & Alam, Touhidul & Teimao, Rui & Thoben, Klaus-Dieter. (2023). Enhancing Pipeline-Based Conversational Agents with Large Language Models.

20. Hussain, Zak & Binz, Marcel & Mata, Rui & Wulff, Dirk. (2023). A tutorial on open-source large language models for behavioral science. 10.31234/osf.io/f7stn.

Study of Machine Learning Models towards Image Classification used in Medical Image Processing

Suhas G. Kulkarni*
✉ kulkarni.suhasg@gmail.com

Rajivkumar Mente
✉ rsmente@sus.ac.in

Department of Computer Applications
School of Computational Science
P.A.H. Solapur University
Solapur, Maharashtra

ABSTRACT

Medical image processing is one of the vital research areas in digital image processing. In digital image processing one important step is classification. The objective of the paper is to study various classification tetchiness that are used in medical image processing. This study is carried out as a part of our study regarding liver image segmentation from CT Scan images to detect liver cancer. In Computer Aided Detection and Diagnosis (CAD) classification step carries a special importance as it reflects as a result. The objective of the study is to understand and present the basic and important classification techniques that are being used in computer-aided detection and diagnosis in medical image processing. The study is intended to understand the pros and cons of the various classification methods used in image processing as well as to understand the suitability of the classification methods in various scenario. The study considers the different types of classification techniques with a focus on KNN, SVM and CNN.

KEYWORDS : *KNN, SVM, CNN, Medical image processing, Machine learning model.*

INTRODUCTION

The process of categorization of all pixels within a digital image into one of several classes is referred as a classification in digital image processing. Image classification aims to find and present the unique features occurring in a digital image as an object. Image classification is one important aspect of digital image analysis. Classification is a complex as well as important task in digital image processing. The steps in image classification are

1) Image acquisition
2) Image Preprocessing
3) Detection of an object (segmentation)
4) Feature extraction and training
5) Classification of the object

Image preprocessing aims to enhance the image quality that make use of techniques like image rescaling, working on image contrast, histogram equalization, use of different image filters, etc.

Segmentation refers to identify and localize an object within a digital image and to detect the position of the object of interest. Extraction of feature refers to identifying the most interesting features and patterns that may confine to a particular class to differentiate the model from other classes or other models. This step is referred to as model building or model training.[1].

Classification steps refer to categorizing the detected object into a predefined class. A suitable classification technique could be used that compares the image patterns/features with the target patterns/features.

STUDY OF MACHINE LEARNING MODEL USED IN IMAGE CLASSIFICATION

The common approaches used in classification are supervised classification, unsupervised classification, semi supervised classification and reinforcement classification etc. The variety of classification models are used in image classification like Support Vector Machines(SVM), Artificial Neural

Networks(ANN), KNN(K Nearest Neighbors), Random Forest(RF), Logistic Regression(LR),Naïve Bayesian Classification(NB), Convolutional Neural Network(CNN) etc.

M. Veeramani Lakshmi and Gandikota K Chakravarthi [1] studied the RF, SVM, LR and NB classification methods on UC merced dataset which is multispectral dataset belongs to remote sensing benchmark. The study observed decision tree performed comparatively better. Alagahkomlavi Atsu[2] and team has observed that the small size dataset may help to produce more accurate results which is not realistic. Data augmentation is one suitable solution for the scenario.

Ritik Singh , Saloni Singh[3] and others studied the different classifiers used in machine learning especially with reference to the classification based on different parameters like nature of pixel information, parameters used on data, nature of spatial information etc.

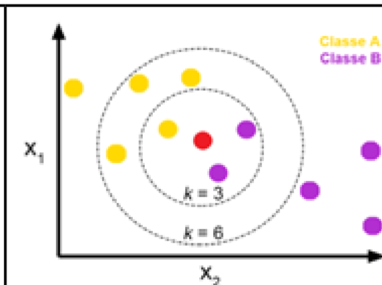
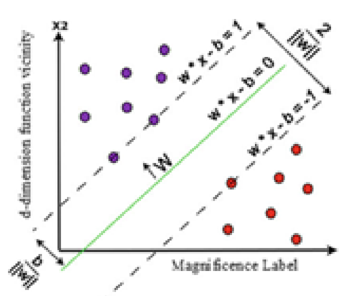
An interesting observation found by Pin Wang , En Fan , Peng Wang[4] in their study that for large size data set CNN perform the better as compared to SVM whereas for small size data set SVM perform better as compared to CNN.

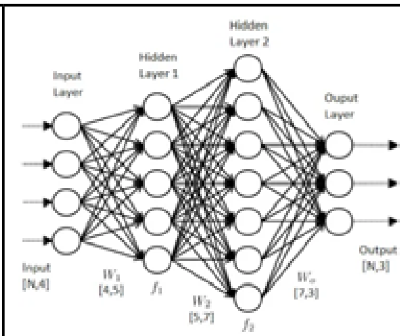
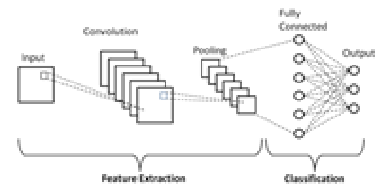
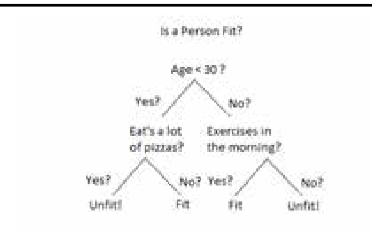
Sayantan Ghosh and Team[5] made an attempt to develop a software tool to analyze structured and unstructured data while automating the classification process by reducing the human intervention.

Maisun Mohamed Alzorgani, Professor Hassan Ugail[6] presented the results of comparison of various machine learning methods to classify the head and neck tumor from histopathological images

The findings of comparative study of various classification methods that are commonly used is presented in Table 1.

Table 1: Comparative Study of Different Classification Methods

Sr. No.	Classification Method	Description	
1	K nearest neighbors (KNN)	- Supervised machine learning - Also known as lazy learners technique - Distance is important factor generally used distances are Minkowski distance, Manhattan distance and Euclidean distance[2] - It is sensitive to outliers. - can be used for regression and classification. - The performance is directly proportional to number of independent variables.	
2	Support Vector Machine (SVM)	- Supervised machine learning - Familiar for both classification and regression. - For linear as well as nonlinear problems it can perform binary classification. - introduced by Vladimir Vapnik in 1965 [2] - The hyperplane selection determines the accuracy of SVM [3] - Applicable for linearly separable and linearly inseparable data[4] -Highly suited for extreme cases of binary classification.	

3	Artificial Neural Network (ANN)	- may be assorted in supervised, unsupervised & reinforcement machine learning - inspired by the biological neural networks that constitute the human brain[2] - hidden layers are like feature detectors	
4	Convolutional Neural Network (CNN)	- Supervised machine learning - Generally requires large data for training - Parameter sharing - The size of tumor is not a matter of concern for CNN as tumor are computed from the image that contains both tumor as well as its surrounding tissues [6].	
5	Decision Tree	- Supervised machine learning - Internal nodes show data set features. - Branches are decision rules - Leaf nodes are outcome. - Graph like flow chart - Able to generate easily interpretable rules. - model is more computationally expensive	
6	Naive Bayes	- built on conditional probabilities - Bayes' theorem is used to calculate the probability - Supervised classification - Popular choice for text classification	$P(A\|B)=\dfrac{P(B\|A)P(A)}{P(B)}$

The classifiers used in machine learning are categorized on the basis of different parameters. Based on the nature of sample used in training classifiers are grouped as supervised and unsupervised classifiers. According to the nature of spatial information spectral classifiers and contextual classifiers. According to various parameters used on data, parameterized classifiers and non-parameterized classifiers.

Classification can also be categorized as pixel-based classification and object-based classification based on pixel information used. Hard classification and soft classification are in accordance with margin used.

CONCLUSION AND FUTURE SCOPE

It is been observed that CNN produces high accuracy. ANN has a fault tolerance ability. SVM supports both linear and nonlinear solutions. KNN becomes significantly slower as the number of independent variables increases. Decision tree is computationally expensive. Naive Bayes is Popular choice for text classification. Findings of study suggest that in medical image processing at beginning KNN would be suitable and in further experimenting journey would be better via SVM, CNN models. To improve the realistic accuracy of classification especially when the data set is small, the data augmentation may prove the helpful. The study has considered the basic and popular classifiers hence further study of more classifiers may enlighten the additional findings.

The presented study focuses on the commonly used classification methods whereas the scope is there to study the different variants of these classification methods. Future scope may also include the detailed study of all classifiers used in last decade. The study explaining the classifier found better with respect to the various datasets may be helpful for research community. The presented study was carried out as a part of our major study related to liver cancer, the scope of our study is restricted to understand the commonly used classifiers along with their suitability with respect to various kind of datasets and its other parameters.

REFERENCES

1. M. Veeramani Lakshmi 2Gandikota K Chakravarthi " COMPARATIVE STUDY FOR MACHINE LEARNING TECHNIQUES TOWARDS IMAGE CLASSIFICATION", 2021 IJCRT | Volume 9, Issue 2 February 2021 | ISSN: 2320-2882
2. Atsu Alagah Komlavi, Kadri Chaibou, Harouna Naroua "Comparative study of machine learning algorithms for face recognition", HAL Id: hal-03620410 https://inria.hal.science/hal-03620410v4
3. Ritik Pratap Singh, Saloni Singh, Ragini Nandan Shakya, and Shahid Eqbal " Comparative Analysis of Different Image Classifiers in Machine Learning", © Springer Nature Singapore Pte Ltd. 2021 A. K. Bhoi et al. (eds.), Advances in Systems, Control and Automations, Lecture Notes in Electrical Engineering 708, https://doi.org/10.1007/978-981-15-8685-9_17
4. Pin Wang , En Fan , Peng Wang " Comparative Analysis of Image Classification Algorithms Based on Traditional Machine Learning and Deep Learning", Pattern Recognition Letters https://doi.org/10.1016/j.patrec.2020.07.042 © 2020 Published by Elsevier B.V.
5. Sayantan Ghosh, Sourav Karmakar, Shubham Gantayat, Sagnik Chakraborty, Dipyaman Saha, and Himansu Das " MLAI: An Integrated Automated Software Platform to Solve Machine Learning Problems", © Springer Nature Singapore Pte Ltd. 2021 A. K. Bhoi et al. (eds.), Advances in Systems, Control and Automations, Lecture Notes in Electrical Engineering 708, https://doi.org/10.1007/978-981-15-8685-9_7
6. Maisun Mohamed Alzorgani, Professor Hassan Ugail " Comparative Study of Image Classification using Machine Learning Algorithms", The 2nd Annual Innovative Engineering Research Conference (AIERC 2018), October. 17, 2018, Bradford, UK
7. Roger Singh Chugh, 2Vardaan Bhatia, 3Karan Khanna, 4Vandana Bhatia " A Comparative Analysis of Classifiers for Image Classification", 10th International Conference on Cloud Computing, Data Science & Engineering (Confluence) 978-1-7281-2791-0/20/$31.00_c 2020 IEEE
8. Chirag Patel, 2Dr. Vimal K. Chaudhari " COMPARATIVE STUDY OF DIFFERENT CLASSIFIERS: AN APPLE FRUIT AS CASE STUDY", www.ijcrt.org © 2018 IJCRT | Volume 6, Issue 2 April 2018 | ISSN: 2320-2882
9. Mahmoud Smaida, Dr. Yaroshchak Serhii " Comparative Study of Image Classification Algorithms for Eyes Diseases Diagnostic", International Journal of Innovative Science and Research Technology ISSN No:-2456-2165 IJISRT19DEC018 www.ijisrt.com Volume 4, Issue 12, December – 2019
10. Seyyid Ahmed Medjahed " A Comparative Study of Feature Extraction Methods in Images Classification", I.J. Image, Graphics and Signal Processing, 2015, 3, 16-23 Published Online February 2015 in MECS (http://www.mecs-press.org/) DOI: 10.5815/ijigsp.2015.03.03
11. Van Hiep Phung 1 and Eun Joo Rhee 2,* " A High-Accuracy Model Average Ensemble of Convolutional Neural Networks for Classification of Cloud Image Patches on Small Datasets", Appl. Sci. 2019, 9, 4500; doi:10.3390/app9214500 ww.mdpi.com/journal/applsci
12. Sunayana G. Domadia, Dr.Tanish Zaveri " Comparative Analysis of Unsupervised and Supervised Image Classification Techniques", National Conference on Recent Trends in Engineering & Technology , 13-14 May 2011 B.V.M. Engineering College, V.V.Nagar,Gujarat,India

Kisan Veggie Basket

Shrinivas Ramanna*
✉ shrinivasramanna.2021@kccemsr.edu.in

Chinmay Jadhav
✉ chinmayjadhav@kccemsr.edu.in

Taraka Phadke
✉ tarakaphadke@kccemsr.edu.in

Aarti Bakshi
✉ aarti.bakshi@kccemsr.edu.in

Department of Electronics & Telecommunications Engineering
KC College of Engineering & Management Studies & Research
Thane, Maharashtra

ABSTRACT

The agriculture sector in India plays a vital role in the economy, yet farmers often face challenges due to the involvement of multiple intermediaries, resulting in unfair pricing and limited profitability. To address these issues, this paper proposes the development of "Kisan Veggie Basket," a mobile application aimed at connecting farmers directly with consumers. By leveraging modern technology and adopting a farm-to-consumer approach, the application facilitates the purchase of fresh, locally sourced agricultural products, thereby empowering farmers and ensuring fair prices. It involves the use of Android Studio with the MVVM architecture for development, promoting reusability and testability. Key features include direct access to fresh produce, reduced food miles, transparency, support for small-scale farmers, convenience, and a feedback loop between consumers and farmers. The proposed solution holds significant promise in revolutionizing the agriculture sector in India, fostering economic empowerment, environmental sustainability, and community engagement.

KEYWORDS *: Farm-to-consumer approach, Locally sourced, Transparency, Direct access, No intermediaries.*

INTRODUCTION

India's agriculture sector plays a pivotal role in its economy, employing a significant portion of the population and contributing substantially to the nation's GDP. This project is aimed at facilitating direct farmer-to-customer communication to ensure greater profitability for Indian farmers. The primary objective of this project is to empower farmers by establishing direct communication channels between farmers and consumers. By cutting out unnecessary intermediaries, farmers can regain control over their produce and negotiate fair prices.

Nowadays, E-Commerce is a really important aspect of our day-to-day life. Existing applications outsource the crops from the farmers to sell them to the customers on their application or website, they act as a middleman between the farmers and consumers. There is no direct connection between farmers and consumers. There is a need for an E-Commerce application solely focused on helping farmers sell their crops at a reasonable price and make them connect with a broader range of consumers.

The "Kisan Veggie Basket" is a mobile application designed to bridge the gap between farmers and consumers by facilitating the purchase of fresh, locally sourced agricultural products. This transformative platform empowers both farmers and consumers, offering farmers the ability to showcase their produce with ease and granting consumers convenient access to a diverse range of farm-fresh goods. Additionally, it offers a mechanism for farmers and consumers to submit grievances with authorized personnel having regular access to address these concerns.

LITERATURE REVIEW

The first paper introduces a smartphone application for geologically detached farmers. the authors have presented a mobile application which is called MobiCrop. This app helps farmers to analyze the amount of pesticides in their fields. However, the paper acknowledges limitations such as mobile device storage needs, usability problems on various devices, security issues with shared certificates, and lacks discussion on high concurrent load system performance. [1]

The second paper introduces a tool developed using Python programming language. The developed tool provides farmers with a user-friendly solution for optimizing crop selection depending on its characteristics to maximize profits. By inputting various constraints and market conditions, farmers can receive recommendations on the optimal combination of crops to plant. However, the paper acknowledges limitations such as simplified assumptions, local context dependence, linear programming approach, limited scope. [2]

The third paper introduces the implementation of web and mobile-based technologies for agriculture marketing, aiming to ensure fair pricing for farmers and efficient access to agricultural products for consumers. Farmers would need to get their products analyzed based on quality criteria by agricultural experts, the application estimates the value of the product. However, the paper acknowledges limitations such as accessibility of web amd mobile technologies, availability of agricultural experts. [3]

The fourth paper introduces a mobile application designed to assist farmers in Sri Lanka with improving cultivation practices and sales. The app aims to address challenges such as market information access, price uncertainty, and weather prediction. It facilitates direct communication between farmers and merchants, offers crop recommendations based on location, and predicts future prices using data mining algorithms. However, the paper acknowledges limitations such as accessibility for disabled individuals, dependence on internet connectivity, and the need for a minimum screen size for optimal user experience. [4]

WORK FLOW PROCESS

The application was essentially developed in Android studio using MVVM (Model-View- Viewmodel) pattern design architecture. Where Model represents the data and business logic of the application. It is responsible for retrieving and manipulating data, as well as enforcing the business rules. The Model notifies the ViewModel about changes in the data. View represents the user interface and is responsible for displaying the data to the user. It observes the ViewModel for updates and ensures that the UI is updated accordingly. ViewModel acts as an intermediary between the Model and the View. It contains the presentation logic and state of the application. The ViewModel retrieves data from the Model, processes it, and exposes it to the View. It also handles user interactions and updates the Model accordingly. Importantly, the ViewModel is designed to be independent of the specific UI components, promoting reusability and testability.

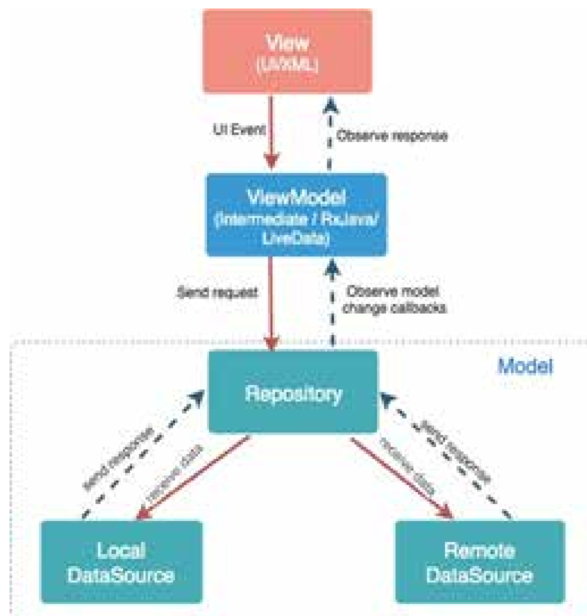


Fig. 1. MVVM Architecture

In Kisan Veggie Basket, the user first needs to login if they already have a account otherwise they have to sign up. Essentially every user is taken to a sign up page made for consumers, if they want to register as a seller there will be a option below to register as a seller. Once they have registered they can login using the login credentials.

Sellers will have options like adding their products, they can view their products that are on sale, and their profile. Whenever they add their products it will be added to the database. Consumers can access this database whenever they want to buy a product. Consumers can buy the products using payment options like Cash on delivery, UPI payments and Debit card payments.

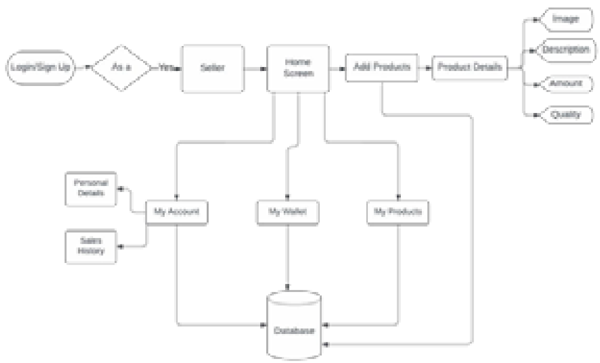


Fig. 2. Seller Account Flow Chart

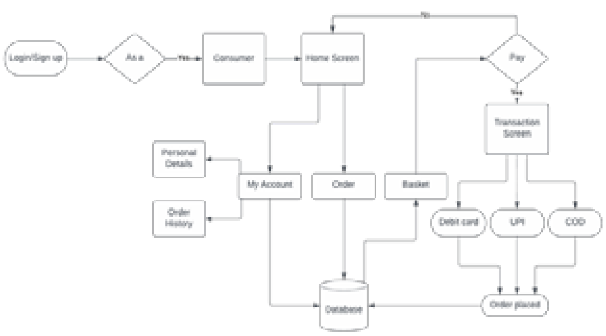


Fig. 3. Consumer Account Flow Chart

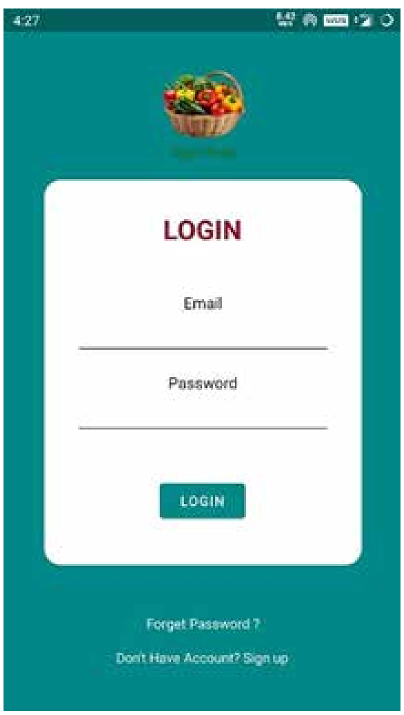


Fig. 4. Login Page

Fig. 5. Consumer Sign up Page

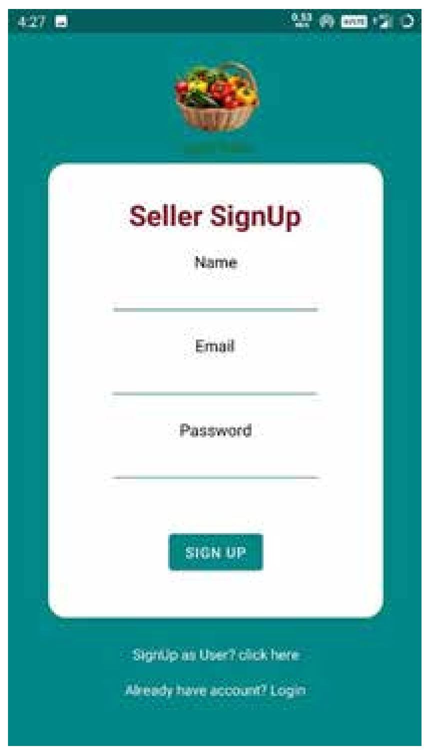


Fig. 6. Seller Sign up Page

PROMINENT FEATURES

1. Direct Access to Fresh Produce: Farm-to-consumer apps provide consumers with direct access to fresh, locally sourced agricultural products. This means that consumers can enjoy fresher and more nutritious produce while supporting local farmers.
2. Reduced Food Miles: By connecting consumers with local farmers, these apps can significantly reduce the distance food travels from farm to table. This reduces the carbon footprint associated with transportation and helps lower greenhouse gas emissions.
3. Transparency and Traceability: Farm-to-consumer apps often provide detailed information about the source of the products. Consumers can trace the origin of the food they purchase, fostering trust and transparency in the supply chain.
4. Support for Small-Scale Farmers: These apps empower small-scale and local farmers by providing them with a platform to reach a broader customer base. This can help small farmers compete with larger, more established agricultural businesses.
5. Convenience: Mobile apps make it convenient for consumers to browse, order, and pay for farm-fresh products from the comfort of their homes. It saves them time and effort compared to visiting physical markets.
6. Feedback Loop: Apps can facilitate direct communication between consumers and farmers, allowing for feedback on product quality and preferences. Farmers can use this information to improve their offerings.

CONCLUSION

In conclusion, this project presents a compelling solution to address the longstanding challenges faced by Indian farmers and consumers in the agriculture sector. By using modern technology and a direct- to-consumer approach, the application aims to streamline the distribution process, eliminate unnecessary intermediaries, and ensure fair prices for farmers while providing consumers with access to fresher, locally sourced produce.

In addition, this application offers a direct, transparent, and empowering solution that supports local agriculture, reduces the carbon footprint, fosters community engagement, and enhances the overall food experience for consumers. Despite some challenges, this app holds tremendous potential for revolutionizing the food industry and creating a more equitable and sustainable food supply chain and it also holds significant promise in empowering farmers, enhancing agricultural sustainability, and fostering greater efficiency and transparency in India’s agriculture sector.

REFERENCES

1. Lomotey, R. K., Chai, Y., Ahmed, K. A., and Deters, R., “Web services mobile application for geographically dispersed crop farmers,” in 2013 IEEE 16th International Conference on Computational Science and Engineering, 2013, pp. 151–158.
2. Romero, J. and Smith, K., “Crop profit optimization for farmers,” in 2016 IEEE Systems and Information Engineering Design Symposium (SIEDS), 2016, pp. 289–291.
3. Abishek, A., Bharathwaj, M., and Bhagyalakshmi, L., “Agriculture marketing using web and mobile based technologies,” in 2016 IEEE Technological Innovations in ICT for Agriculture and Rural Development (TIAR), 2016, pp. 41–44.
4. A. Nirojan, V., “Smart cultivation partner - mobile application (android) service to increase cultivation and sales,” in 2017 International Journal of Scientific and Research Publications, Volume 7, Issue 12, 2017, pp. 2250–3153.

Examining the Capabilities of Machine Intelligence Techniques for Image-based Litter Classification: Aspects, Trends and Challenges

Preet Kamal Kaur*
✉ preetkamalkaur06@gmail.com

Nirvair Neeru

Department of Computer Science and Engineering
Punjabi University
Patiala, Punjab

ABSTRACT

Due to continuous surge in population growth and urban development, there has been a notable rise in the production of solid waste worldwide. In order to align with the sustainable development goals, researchers have redirected their focus towards discovering the innovative solutions to tackle the waste management issue. Recycling emerges as an efficient approach to waste handling, with the initial step being the segregation of waste into different categories at its source. Manual waste sorting is labour-intensive, time-consuming, prone to inaccuracy and potentially harmful to health. Image processing, artificial intelligence, machine learning, and deep learning based techniques contribute to develop the intelligent systems that can extract distinctive features from waste items and categorize them into specific classes. Paper commences with the discussion of the types of solid waste and emphasizes the need of automation for waste classification to mitigate the environmental deterioration. It proceeds with the in-depth analysis of recent methods applied in the domain, ranging from conventional ML-based techniques to advanced and complex DL architectures. Study paves the way for growth in the field by putting forward the evolving trends, presents the challenges and research directions to promote and support sustainable solid waste management practices.

KEYWORDS *: Waste classification, Sustainable development, Machine learning, Deep learning, Detection.*

INTRODUCTION

Due to accelerating patterns of urbanization and population expansion, the amount of waste produced annually will surge from 2.24 billion tonnes in 2020 to 3.88 billion tonnes of solid waste in 2050 (approximately 73% increase in 30 years) [1]. Growing amount of solid trash in urban regions is a major concern because, if left unchecked, it might pollute the environment and endanger the health of living beings (terrestrial and aquatic). Inadequate waste management can lead to profound repercussions for earth including water pollution, air contamination, soil erosion, unpredictable climatic changes and degradation of biodiversity. Health and welfare of both people and animals are endangered as a result of these effects. Proper and efficient management of waste entails a systematic process that begins with its generation and extends to recycling or disposal. Landfilling and incineration are commonly used methods for waste disposal, each of which poses adverse effects on human health or the environment in one form or another. Therefore, it is imperative to prioritize the waste recycling to safeguard the ecosystem and a fundamental aspect of this procedure is to separate or sort the garbage into distinct categories (components) [2, 3]. Fig. 1 below shows the major types of solid waste as per their source:

Generally, sorting is done manually resulting in substantial overhead in terms of money, time and labour. Moreover, persons directly engaged in the process are susceptible to various infectious agents and there is a possibility of large number of errors [2, 4]. Consequently, researchers are focussing their efforts towards the development of an automated system that categorizes the solid waste (based on its' features) in short amount of time, yet with more efficacy and accuracy. In recent years, algorithms and models have been deployed for intelligent and automated sorting of solid waste. These methods extract visual characteristics (such as color, texture, shape, etc.) associated with specific waste items from the image-based waste datasets. These features are then utilized to train Artificial Intelligence, Machine Learning or Deep Learning models [5]. Intelligent machine learning algorithms learn through the training data, fine-tune themselves based on validation data and finally, get evaluated using the testing or unseen data. With the application of automation methods, waste can be categorized, segmented and localized. Some of the popular techniques observed in the literature are Decision Tree, Random Forest [6], Support Vector Machine [2, 7], k-nearest Neighbor [7, 8], Logistic Regression [7, 9], Artificial Neural Network [10], Convolution Neural Network based models [11, 12].

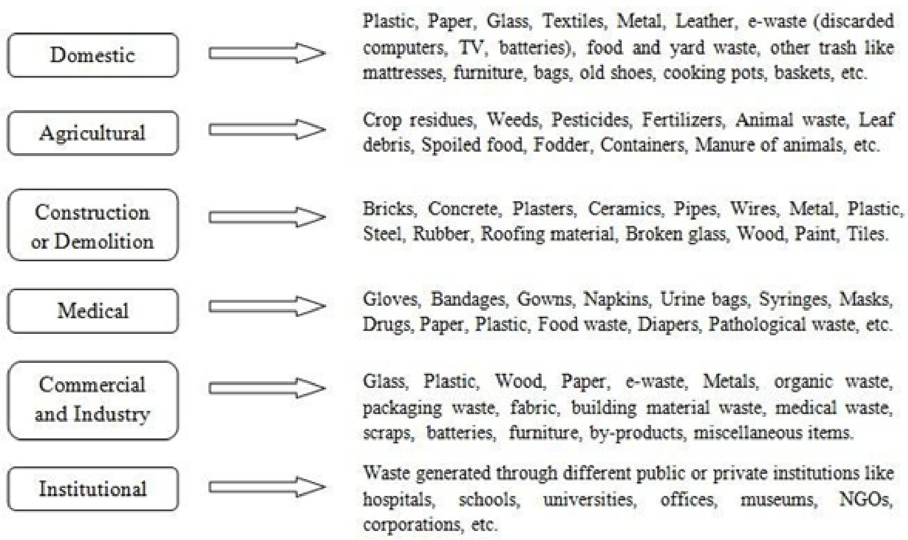


Fig. 1: Types of Waste

Paper aims to explore the latest research trends in intelligent solid waste recognition and segregation. Implementing an automated solid waste sorting system alleviates ecological harm, encourages the recycling, lowers the amount of waste dumped in landfills and eventually fosters the sustainable waste management. Subsequent sections of the paper delves into the latest methods applied in the field, examining their relevance with respect to different parameters, outlining critical challenges and research directions that require attention.

ANALYSIS OF RECENT RESEARCH

Table below presents the analysis of the latest research papers related to the field. Papers are reviewed on the basis of different factors such as type of waste, technique applied, respective results and the limitations encountered.

Author & Year	Waste type	Technique	Remarks	Future Scope
Ruiz et al. [12], 2019	Metal, plastic, cardboard, glass, paper, other trash	VGG-16, VGG-19, Inception, ResNet, InceptionResNet	Best results obtained with InceptionResNet i.e. 88.66% accuracy.	Training the model with synthetic (garbage) images and testing with real images.
Sami et al. [13], 2020	Glass, paper, plastic, metal, cardboard, trash	Random Forest, SVM, CNN, Decision tree	CNN followedb y SVM, performed better than other models.	----

Adadeji & Wang [2], 2019	Plastic, metal, glass, paper	CNN as feature extractor and VM for classification	87% accuracy achieved through the combination of CNN and SVM.	Classifying more number of waste classes by tuning the parameters. Adding more images to enhance accuracy.
Faria et al. [11], 2021	Metal, glass, plastic, organic waste	Three-layer CNN, InceptionV3, ResNet50, VGG16, and VGG19.	VGG16 best among all the models with 88.42% accuracy.	Addition of real-world images for model training. Embedding hardware in the model to make a robot for waste collection.
Chu et al. [14], 2018	50 waste items: 40 recyclable and 10 others.	AlexNet CNN for feature extraction, multi-layer perceptron to classify waste (multi-layered hybrid system)	Proposed method gives better accuracy than CNN model. Improvement in performance with combined numerical feature data.	CNN, when applied alone, is not able to perform where waste item has fewer features to differentiate (especially in the case of other waste).
Mao et al. [15], 2020	Plastic, paper, metal, glass, cardboard, trash	DenseNet CNN (fine tuning of classification layer using genetic algorithm)	Augmentation and optimization significantly improved the results for sorting.	Detecting multiple objects. Testing the robustness of the model by collecting more real-time images.
Desai et al. [16], 2018	Categorization into biodegradable and non-biodegradable waste	CNN	System is developed using sensors and micro-controllers. Capability is limited to metal like objects.	Applying latest (advanced) ML techniques to enhance the performance.
Ramsurrun et al. [17], 2021	Paper, plastic, metal, glass, trash, cardboard	12 different variants of CNN with 3 main classifiers: Sigmoid, SoftMax, SVM	VGG19 + Softmax exhibited accuracy of 88%, model successful in classifying 5 out of 6 classes.	Combining optimization with ML models to enhance the performance. Detection in real time using IoT devices.
Gomez et al. [7], 2021	Plastic, paper, metal, glass, cardboard, trash	SVM, K-NN, Logistic regression	SVM paired with PCA dimensionality reduction gave better results.	Implementing neural nets merged with transfer learning. Multi-class classification using large datasets.
Ahmed et al. [18], 2023	Metal, glass, plastic, paper, others	CNN, MobileNet, DenseNet, ResNet	Pre-trained models better than state-of-the-art CNN. ResNet proved best.	Augmentation of data. Testing robustness of model. Applying latest techniques like ensemble learning or fusion-based.
Zhou et al. [19], 2022	8 categories of medical waste such as gloves, syringes, syringe needles, infusion bags and bottles etc.	ResNeXt combined with transfer learning strategies.	Accuracy is around 97%. Average f-score for the classification is 97.2% when tested with 5 fold cross validation.	Fine-tuning the model for objects which are having similar features as well as for soft objects which change their shape while folding.

Zhang et al. [20], 2021	Waste metal, plastic, paper, fabric and glass.	DenseNet (pre-trained on ImageNet data using transfer learning)	DenseNet + transfer learning performed better than 4 other CNN-based models (such as VGG16) applied without transfer learning.	Boosting the model's capacity to handle objects with backgrounds that are more like the real world.
Nnamoko et al. [21], 2022	Organic and Recyclable waste	Bespoke lightweight 5 layer CNN	Models trained on different resolution images: 225*264 & 80*45. Smaller model produced more accuracy, larger model more generalizable but complex.	Fine-tuning and analyzing the model based on different parameters. Before retraining, focus on removing incorrectly labelled images.
Srinilta and Kanharattana hai [22], 2019	Household waste categorized majorly into compostable, recyclable, hazardous and general.	ResNet50, DenseNet121, VGG16, ResNet50	All models achieved above 80% accuracy. ResNet-50 outperformed all with 91.30% performance.	Capability of the model can be extended by training it with a bigger MSW dataset and tuning the parameters to deal with different waste categories.
Vo et al. [23], 2019	Organic, Medical, Inorganic waste	DNN-TC (Deep Neural Net for Trash classification) improvement of ResNExt	94% accuracy for the TrashNet (existing) dataset and 98% for collected VN trash data.	Model should handle the situations where there is an imbalance in the quantity of images across different waste classes. Segmentation in pre-processing phase.
He et al. [24], 2021	Plastic, Paper, Trash, Metal, Glass Cardboard	Modified ALexNet with SVM and Softmax as last layer (classification)	Highest accuracy achieved is approx. 80% when using SVM as a classifier alongside partial augmentation.	Applying transfer learning and exploration of models like ResNet, VGG.
Karthikeyan et al. [25], 2021	Wood, e-waste, Cardboard, Paper, Glass, Metal, Plastic.	Double fused CNN based on ResNext (DDR-Net)	97.3% accuracy achieved by DDR-net. Better than DNN TC [23], which has 93% accuracy when applied on the same dataset as DDR-net.	Increasing the size of a dataset with more valid waste images. Applying the model in real-time bin systems (using IoT) for waste segregation.

CHALLENGES

- Dataset required to train the waste sorting or detection model should be sufficiently extensive to handle the diverse real time conditions. However, in practice, obtaining a satisfactory volume of data is not always feasible, which may affect the algorithm' performance in complex scenarios.
- Classification or detection models take into account the limited range of waste categories. But, a wide variety of solid waste items exists in real-time. Emphasis should be on the specificity of waste instances during the model development process.
- Waste items become obscured by other objects, concealing the features crucial for their identification. For instance, cold drink bottle covered by its label represents the case of partial occlusion, which hinders the view of underlying attributes such as shape, texture or colour, making the classification process more complicated.
- At times, the characteristics of waste items within the same category may vary significantly, while those from different categories might exhibit similarities. This can pose a challenge for the model in learning distinct features associated with a particular item.

- Model trained on the certain data (dataset) may sometimes find it difficult to generalize in the situations different from that of training phase i.e. there is no assurance that it will perform efficiently on the unseen data as well.

CONCLUSION

To deal with the continuous production of large quantity of solid waste on the daily basis, automated waste management is necessary. Waste segregation, which involves sorting the waste into different categories, is one of the primary and crucial steps in the entire waste handling process. Computer-assisted technologies such as Artificial intelligence, Machine learning and deep learning have proven their effectiveness in addressing the waste classification challenges with minimal human intervention. These techniques scrutinize large and varied image-based waste datasets to recognize the waste items based on attributes such as texture, colour, shape, and more. Paper discusses the scope and benefits of leveraging machine intelligence for automated waste sorting and offers a thorough analysis of the latest research papers related to the domain. Study outlines the challenges and limitations in the field, which could serve as motivation for the researchers to undertake further work in the future. AI, ML and DL based algorithmic approaches significantly enhance the efficiency and accuracy of solid waste segregation when compared to traditional methods. However, given the complex and challenging nature of the task, there remains ample scope for advancements to ensure the smooth applicability in the real world scenarios.

REFERENCES

1. The World Bank, Solid Waste Management, 11 February 2022.
2. Adedeji, O., & Wang, Z. (2019). Intelligent waste classification system using deep learning convolutional neural network. Procedia Manufacturing, 35, 607-612.
3. Nanda, S., & Berruti, F. (2021). Municipal solid waste management and landfilling technologies: a review. Environmental chemistry letters, 19(2), 1433-1456.
4. Flores, M. G., & Tan, J. (2019). Literature review of automated waste segregation system using machine learning: A comprehensive analysis. International journal of simulation: systems, science and technology, 11.
5. Li, N., & Chen, Y. (2023). Municipal solid waste lassification and real-time detection using deep learning methods. Urban Climate, 49, 101462.
6. Sami, K. N., Amin, Z. M. A., & Hassan, R. (2020). Waste management using machine learning and deep learning algorithms. International Journal on Perceptive and Cognitive Computing, 6(2), 97-106.
7. Gómez, D. O., Toro, M., & Hoyos, W. (2021). Solid Domestic Waste classification using Image Processing and Machine Learning.
8. Satvilkar, M. (2018). Image based trash classification using machine learning algorithms for recyclability status (Doctoral dissertation, Dublin, National College of Ireland).
9. Goel, S., Markanday, S., & Gupta, A. (2023, December). A Deep Dive into Accurate Garbage Classification Using Transfer Learning Techniques for Environmental Sustainability. In 2023 9th International Conference on Signal Processing and Communication (ICSC) (pp. 209-213). IEEE.
10. Mohammed, M. A., Abdulhasan, M. J., Kumar, N. M., Abdulkareem, K. H., Mostafa, S. A., Maashi, M. S., ... & Chopra, S. S. (2023). Automated waste-sorting and recycling classification using artificial neural network and features fusion: A digital-enabled circular economy vision for smart cities. Multimedia tools and applications, 82(25), 39617-39632.
11. Faria, R., Ahmed, F., Das, A., & Dey, A. (2021, September). Classification of organic and solid waste using deep convolutional neural networks. In 2021 IEEE 9th Region 10 Humanitarian Technology Conference (R10-HTC) (pp. 01-06). IEEE.
12. Ruiz, V., Sánchez, Á., Vélez, J. F., & Raducanu, B. (2019). Automatic image-based waste classification. In From Bioinspired Systems and Biomedical Applications to Machine Learning: 8th International Work-Conference on the Interplay Between Natural and Artificial Computation, IWINAC 2019, Almería, Spain, June 3–7, 2019, Proceedings, Part II 8 (pp. 422-431). Springer International Publishing.
13. Sami, K. N., Amin, Z. M. A., & Hassan, R. (2020). Waste management using machine learning and deep learning algorithms. International Journal on Perceptive and Cognitive Computing, 6(2), 97-106.
14. Chu, Y., Huang, C., Xie, X., Tan, B., Kamal, S., & Xiong, X. (2018). Multilayer hybrid deep-learning method

for waste classification and recycling. Computational intelligence and neuroscience, 2018.

15. Mao, W. L., Chen, W. C., Wang, C. T., & Lin, Y. H. (2021). Recycling waste classification using optimized convolutional neural network. Resources, Conservation and Recycling, 164, 105132.
16. Desai, Y., Dalvi, A., Jadhav, P., & Baphna, A. (2018). Waste segregation using machine learning. International Journal for Research in Applied Science and Engineering Technology, 6, 537-541.
17. Ramsurrun, N., Suddul, G., Armoogum, S., & Foogooa, R. (2021, May). Recyclable waste classification using computer vision and deep learning. In 2021 zooming innovation in consumer technologies conference (ZINC) (pp. 11-15). IEEE.
18. Ahmed, M. I. B., Alotaibi, R. B., Al-Qahtani, R. A., Al-Qahtani, R. S., Al-Hetela, S. S., Al-Matar, K. A., ... & Krishnasamy, G. (2023). Deep Learning Approach to Recyclable Products Classification: Towards Sustainable Waste Management. Sustainability, 15(14), 11138.
19. Zhou, H., Yu, X., Alhaskawi, A., Dong, Y., Wang, Z., Jin, Q., ... & Lu, H. (2022). A deep learning approach for medical waste classification. Scientific reports, 12(1), 2159.
20. Zhang, Q., Yang, Q., Zhang, X., Bao, Q., Su, J., & Liu, X. (2021). Waste image classification based on transfer learning and convolutional neural network. Waste Management, 135, 150-157.
21. Nnamoko, N., Barrowclough, J., & Procter, J. (2022). Solid waste image classification using deep convolutional neural network. Infrastructures, 7(4), 47.
22. Srinilta, C., & Kanharattanachai, S. (2019, July). Municipal solid waste segregation with CNN. In 2019 5th International conference on engineering, applied sciences and technology (ICEAST) (pp. 1-4). IEEE.
23. Vo, A. H., Vo, M. T., & Le, T. (2019). A novel framework for trash classification using deep transfer learning. IEEE Access, 7, 178631-178639.
24. He, Y., Gu, Q., & Shi, M. (2020). Trash Classification Using Convolutional Neural Networks Project Category: Computer Vision.
25. Karthikeyan, S., Sivakumar, M., Jeysiva, A. P., & Maheshkumar, C. (2021). Application of deep learning for solid waste trash classification using deep CNN. In Proceedings of ACM/CSI/IEEECS Research & Industry Symposium on IoT Cloud for Societal Applications.

PsychePulse: ML-based Mental Health Identifier

Abhishek Kumar*, Devendra Girase
Swathi Bandi, Vedant Swami
UG Scholar
Department of Electronics and Telecomm. Engineering
K C College of Engg, & Mamt Studies & Research
Thane, Maharashtra
✉ abhishekshukla06822@gmail.com

Anupama Chaurasia
Assistant Professor
Department of Electronics and Telecomm. Engineering
K C College of Engg, & Mamt Studies & Research
Thane, Maharashtra
✉ abhishekshukla06822@gmail.com

ABSTRACT

PsychePulse is an innovative mental health identification system leveraging machine learning techniques for accurate assessment. The Kotlin-native Android app provides a complete solution for administrators and users alike. Users can register, log in, and undergo mental health assessments using a multi-modal approach—capturing responses through text, speech, and facial expressions. The app employs NLP and emotion analysis APIs for emotion recognition, enhancing the accuracy of mental health evaluations. The system categorizes mental disorders such as depression, anxiety, OCD, and bipolar disorder based on user responses and facial expressions, providing recommendations based on the assessment score. Additionally, the app features a daily health condition report and a feedback mechanism. For administrators, the system facilitates user management, test history viewing, recommendation management, and feedback analysis, with the backend powered by a MySQL database for secure and efficient data storage. PsychePulse aims to bridge the gap in mental health awareness and support by providing a reliable tool for self-assessment and recommendations, enhancing the accuracy of mental health evaluations through its multi-modal input and advanced machine learning techniques.

KEYWORDS *: Android studio, Bipolar disorder, Depression, Emotion analysis, Kotlin, Machine learning, Mental health, Natural language processing, NLP, OCD, Recommendation system, Speech recognition.*

INTRODUCTION

An integral part of a person's total health is their mental state, which includes their emotional, psychological, and social well-being. The intricate nature of mental health conditions necessitates timely and accurate assessment for effective diagnosis and intervention. Traditional screening methods often involve self-report questionnaires, which provide insights into an individual's attitudes and sensations related to social interactions[1]. Embracing technology, particularly in Machine Learning (ML) and Artificial Intelligence (AI), offers a transformative approach to mental health assessment and prediction.

ML, a subset of AI, addresses classification, regression, and clustering problems by leveraging data and algorithms to emulate human learning processes. Applied extensively in psychological treatments, ML exhibits significant promise in predicting and treating mental health conditions. Supervised learning, a prominent ML approach, involves the understanding of a mapping between input variables and an output variable to predict outcomes of unseen data [3]. Classification and prediction of mental health disorders based on diverse data features can be achieved using techniques such as Support Vector Machines (SVM), Decision Trees, Logistic Regression, and Naïve Bayes.

Ensemble learning, another ML paradigm, amalgamates multiple individual learners to form a robust model. Techniques such as Bagging, Boosting, and Stacking enhance predictive accuracy by combining outputs from diverse learners. Random Forest and Extreme Gradient Boosting (XGBoost) exemplify widely-used ensemble learning methods, demonstrating effectiveness in decision tree-based modeling.

The exploration of Transfer Learning opens new dimensions in psychological research, allowing knowledge from related tasks to improve learning in novel domains. [4]. Deep Learning (DL), a subfield of ML, stands out for its ability to automatically discern distinctive characteristics in unstructured data, such as text and images.The combined use of DL and ML represents a significant shift in mental health diagnosis methodologies.

There has been notable advancement in the application of machine learning (ML) in the medical field, particularly with regard to the identification of mental health disorders.ML algorithms analyze data from Electronic Health Records (EHRs) and wearable devices, offering continuous monitoring and early detection possibilities. Predictive modelling aids in identifying individuals at risk, enabling timely interventions to prevent severe mental health issues. By means of a thorough examination of the approaches used in the last ten years, this research attempts to offer a thorough overview of the field's progress, difficulties, and prospects.

The following sections provide an overview of mental health issues, explain the methodology for selecting and analyzing data, and comprehensively explore machine learning (ML) and deep learning (DL) methodologies. The analysis and discussion segment dissects the findings, emphasizing challenges and opportunities, while the concluding section encapsulates the key takeaways of this research endeavor.

LITERATURE REVIEW

Iyortsuun et al. [1] conducted a review of machine learning and deep learning approaches for mental health diagnosis, highlighting various advancements in the field. They emphasized the significance of these approaches in improving mental health diagnostics.

Ehiabhi and Wang [2] systematically reviewed machine learning models in mental health analysis based on multi-channel multi-modal biometric signals, showcasing the effectiveness of these models in analyzing complex data. Their study provides valuable insights into the application of machine learning in mental health analysis.

Pinaya et al. [3] utilized deep autoencoders to identify abnormal brain structural patterns in neuropsychiatric disorders, demonstrating the potential of deep learning in understanding brain disorders. Their large-scale study contributes to the field of neuropsychiatry.

Jo et al. [4] employed network analysis and a machine learning method to diagnose schizophrenia, showcasing the utility of machine learning in psychiatric research. Their study provides insights into novel diagnostic approaches for schizophrenia.

Chauhan and Jaiswal [5] proposed an efficient data mining classification approach for detecting lung cancer disease, highlighting the importance of data mining in healthcare. Their approach offers a promising method for the early detection of lung cancer.

Olfson et al. [6] studied psychiatric disorder onset and first treatment contact in the United States and Ontario, revealing differences in healthcare systems. Their findings underscore the importance of timely treatment for mental health disorders.

Mueller et al. [7] investigated recurrence after recovery from major depressive disorder during 15 years of observational follow-up, providing insights into long-term outcomes. Their study sheds light on the challenges of managing depression.

Rutledge et al. [8] discussed machine learning and big data in psychiatry, highlighting their potential for clinical applications. Their review emphasizes the transformative impact of technology in mental health care.

Jordan and Mitchell [9] provided an overview of machine learning trends, perspectives, and prospects, highlighting its relevance in various fields, including psychiatry. Their insights contribute to our understanding of the broader impact of machine learning.

Cho et al. [10] reviewed machine learning algorithms for diagnosing mental illness, emphasizing the importance of accurate diagnosis for effective treatment. Their review provides a comprehensive analysis of the current state of machine learning in mental health diagnostics.

Lad et al. [11] developed a machine learning-based resume recommendation system, showcasing the application of machine learning in different domains. Their system demonstrates the potential of machine learning for optimizing recruitment processes.

The literature review examines the use of machine learning (ML) techniques in predicting mental health disorders, including schizophrenia, depression, anxiety, bipolar disorder, PTSD, and mental health problems in children. Thirty research publications were analyzed, revealing diverse ML approaches to schizophrenia prediction. For instance, Jo et al. (2020) used random forest, multinomial naive Bayes, XGBoost, and SVM, achieving accuracies above 70 for anxiety and depression. Inconsistent results were observed in bipolar disorder prediction. Studies on PTSD mainly used random forest and SVM, with Marmar et al. (2019) achieving 89.1% accuracy. Regarding children's mental health, various ML models were used, with multilayer perceptron achieving the highest accuracy of 78%. Overall, ML algorithms, particularly random forest and SVM, show promise in predicting mental health disorders, but further research and possibly ensemble approaches are needed to improve accuracy.

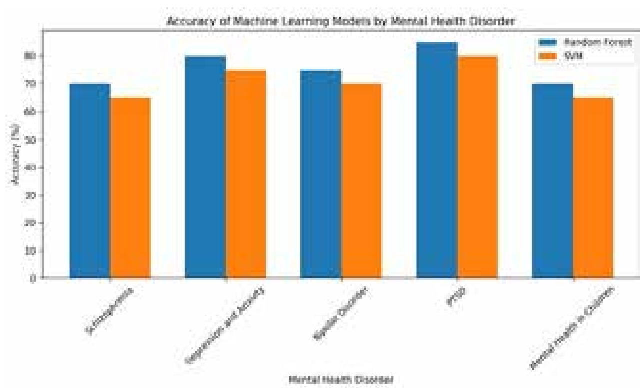


Figure 1: Accuracy of ML Models

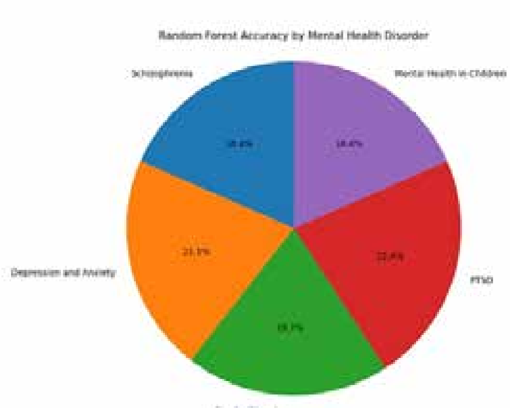


Figure 2: Random Forest Accuracy

Table 1: Summary of Key Studies on Mental Health and Machine Learning

Author, Year	Mental Health Problem	Machine Learning Model	Performance	Comments
Srinivasagopalan et al., 2019	Schizophrenia	Deep learning, SVM, Random forest, Logistic regression	Deep learning: 94.44%, SVM: 82.68%, Random forest: 83.33%, Logistic regression: 82.77%	Implemented a novel approach for combining multiple classifiers
Sau and Bhakta, 2017	Depression and Anxiety	Bayesian network, Naive Bayes, Logistic regression, MLP, Sequential minimal optimization, K-star, Random subspace, J48, Random forest, Random tree	Bayesian network: 79.8%, Naive Bayes: 79.6%, Logistic regression: 72.4%, MLP: 77.8%	Evaluated the performance of multiple ML algorithms on a large dataset
Ahmed et al., 2019	Depression and Anxiety	Convolutional neural network	Anxiety: 96.0%, Depression: 96.8%	Proposed a CNN-based model for improved diagnosis
Sau and Bhakta, 2019	Depression and Anxiety	CatBoost, Logistic regression, SVM, Naive Bayes, Random forest	CatBoost: 89.3%, Logistic regression: 87.5%, SVM: 87.5%, Naive Bayes: 82.1%, Random forest: 78.6%	Compared the performance of various ensemble methods
Hilbert et al., 2017	Anxiety	SVM	Case classification: 90.10%, Disorder classification: 67.46%	Utilized multimodal data for anxiety disorder classification

EASE OF USE

A. User-Friendly Interface: PsychePulse features a user-friendly interface for a seamless and intuitive experience for administrators and users alike. The application's layout allows effortless navigation through its various features.

B. Accessibility: For PsychePulse, accessibility for a wide range of users is essential. The interface is inclusive of people from a variety of age groups and backgrounds since it is made to work with users who have diverse degrees of technological proficiency.

C. Intuitive Functionality: Because PsychePulse has intuitive functionality, users may easily register, log in, and browse through the application's various areas. The design decisions put emphasis on simplicity and clarity without sacrificing feature richness and depth.

D. Responsive Design: The application is optimized for various devices and screen sizes, providing a consistent and responsive experience across smartphones, tablets, and desktops. This flexibility guarantees that consumers, irrespective of the device they are using, may effortlessly access PsychePulse.

E. Robust Administrative Tools: A comprehensive range of tools that simplify and expedite work is advantageous for administrators. Because of the efficient design of the admin interface, administrators can easily view user data, manage suggestions, and respond to user feedback.

F. Continuous Improvement: PsychePulse is dedicated to enhancing the user experience throughout time. Updates are actively seeking and incorporating feedback from administrators and users to make sure the application adapts to the changing needs of its user base.

DATA SELECTION, RETRIEVAL, AND ANALYTICAL METHODOLOGY

A. Thoughtful Considerations: Several pivotal thoughts and questions guided the review process:

1) Recent Methodologies: Exploring the most recent techniques utilized by researchers in the field of machine learning for diagnosing mental illnesses.

2) Challenges Faced: Being aware of the difficulties faced by researchers in this ever-changing subject.

3) Dataset Compilation: Establishing a database of freely available datasets to act as a useful tool for 3 machine learning researchers.

B. Database Exploration: Reputable databases such as PubMed, Google Scholar, Scopus, and Web of Science were searched between 2013 and 2022. Key search terms such as "Artificial Intelligence for mental health diagnosis" and "Machine Learning for mental health prediction" were employed.

C. Mental Health Condition Representation: This exhaustive investigation guarantees a varied portrayal of every mental health disorder examined, offering an exhaustive synopsis of the terrain.

D. Adherence to Reporting Guidelines: The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) criteria, which are an improved version of the Quality of Reporting of Meta-analyses (QUOROM Statement), were followed in the processing of the results. PRISMA integrates recent theoretical and applied developments in systematic review science.

A detailed PRISMA flow diagram outlines the process for choosing and integrating the literature. After each publication was thoroughly scrutinized, articles that did not meet the selection criteria were eliminated under the following circumstances:

1. Irrelevant to the subject of the study.
2. Insufficient rigor in the methodology.
3. Duplicate publications.
4. Non-English language.
5. Inaccessible full text.
6. Publication date outside the defined timeframe.
7. Studies focusing on non-human subjects.
8. Publications without peer review.
9. Articles without available abstracts.

METHODOLOGY

Research Design: The research adopts a mixed-methods approach, combining qualitative and quantitative techniques. It entails the creation and testing of PsychePulse, a machine learning-based mental health assessment tool that incorporates behavioral markers, user inputs, and face expressions.

Participants (or Sample): The study includes a diverse sample of participants, primarily adults aged 18 and above, recruited through online platforms and mental health organizations. Participants must have basic proficiency in English and access to an Android phone (6.0 and above) for app usage.

Materials (or Apparatus): The main resources include several machine learning methods for data analysis, Azure Data Studio for data administration, and Android Studio for app development. Standard psychological assessment questionnaires and scales are also employed for validation.

Procedure: The research involves several stages:

1. ThePsychePulseappwas developed with Android Studio and includes functionality for managing profiles, logging in, registering users, and conducting mental health assessments.

2.Applicationof machine learning techniques for user input and facial expression analysis to analyze emotions.

3. A small number of users will pilot test the app to find any usability problems and improve the tool.

4. Full-scale deployment and data collection from a larger sample of participants.

5. Analysis of collected data using statistical methods and machine learning algorithms to evaluate the effectiveness of PsychePulse in identifying mental health conditions.

Data Analysis: Descriptive statistics are used to assess the collected data in order to compile participant demographics and mental health profiles. Furthermore, the association between user inputs, face expressions, and mental health outcomes is investigated through the use of inferential statistics. Ethical Considerations: The study complies with ethical standards, which include getting each participant's informed consent, protecting participant data confidentiality, and giving them access to services and help for mental health issues during the study.

Limitations: Limitations include the reliance on self-reported data, potential biases in participant selection, and the app's language limitation to English, which may impact the generalizability of the findings.

Validity and Reliability: The software is put through pilot testing to enhance its functionality and increase its validity in identifying mental health disorders. The application of rigorous data gathering processes and standardized assessment scales improves reliability.

Results: According to preliminary results, PsychePulse has a high level of user happiness and engagement and is useful for assessing mental health issues. We'll do more research to confirm these results and evaluate the tool's long-term effects.

Future Research: Future research could focus on expanding PsychePulse to support multiple languages, conducting longitudinal studies to assess the tool's long-term effectiveness, and integrating additional features for personalized mental health recommendations.

RESULT

PsychePulse App Development: The development of the PsychePulse app was successful using Android Studio, integrating features such as user registration, login, profile management, and mental health assessment tools.

Machine Learning Integration: Machine learning algorithms were successfully implemented for emotional analysis based on user inputs and facial expressions, enhancing the app's ability to assess mental health conditions.

Participant Recruitment: A diverse sample of participants, primarily adults aged 18 and above, were recruited through online platforms and mental health organizations, ensuring a varied demographic representation.

Data Collection and Analysis: Data collection involved pilot testing with a small group of participants to identify usability issues and refine the app, followed by full-scale deployment and data collection from a larger sample. Data analysis included descriptive and inferential statistics to evaluate the effectiveness of PsychePulse in identifying mental health conditions. Ethical Considerations: Ethical guidelines, including informed consent, participant confidentiality, and access to mental health resources, were adhered to throughout the study. Preliminary Findings: Preliminary findings indicate that PsychePulse is effective in assessing mental health conditions, with high user satisfaction and engagement. Further analysis will validate these findings and assess long-term impact.

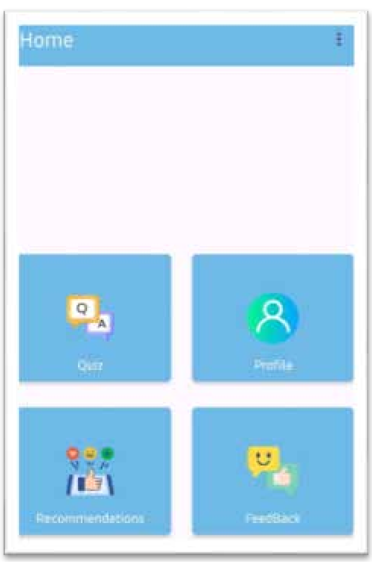
Future Research: Future research could focus on expanding PsychePulse to support multiple languages, conducting longitudinal studies to assess long-term effectiveness, and integrating additional features for personalized mental health recommendations.

PsychePulseconsists of two modules: one for administrators and another for users. PsychePulse's two-module architecture makes it possible to distinguish clearly between the features and functionalities intended for administrators, who oversee the system, and users, who engage with the features and tools for mental health assessments.

Users of PsychePulse can take tests, sign up, log in, provide comments, and get alerts when there are test gaps. Reports are generated by the system depending on test results.

PsychePulse's admin interface is a centralized hub for managing the app, offering user profile management, test history viewing, and feedback analysis. Administrators can navigate user data, view assessment results, and provide personalized recommendations for effective monitoring and support. The user-centric design enables administrators to oversee interactions and customize interventions for improved mental health outcomes.

Figure 3: User module for PsychePulse



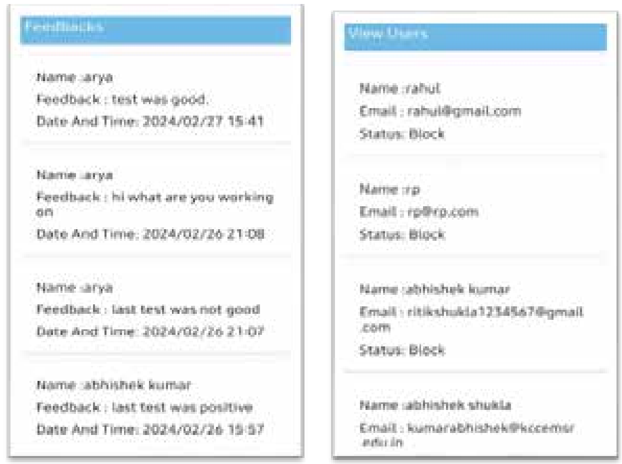


Figure 4: Admin module for PsychePulse

FUTURE DIRECTIONS

Global Expansion: Increase the app’s exposure to foreign markets by offering bilingual assistance and material that is sensitive to cultural differences.

Constant Improvement: Add new features and updates to the app on a regular basis in response to user input and technical developments.

Research Collaboration: Work together with researchers and mental health specialists to verify the app’s efficacy and further the development of mental health assessment instruments.

Community Engagement: Create a vibrant online community centered around the app by offering assistance, materials, and a forum for users to discuss difficulties and experiences.

Integration with Healthcare Systems: Connect the app to healthcare systems so that mental health information and advice can be easily shared with medical professionals.

Data Security and Privacy: To safeguard user information and foster user trust, uphold the strictest standards for data security and privacy.

Education and Awareness: In order to lessen the stigma attached to asking for help, keep up your education on mental health issues and raising awareness among users.

Make sure the software is both accessible to users with disabilities and scalable to handle an increasing user base. Conduct longitudinal research to evaluate the app's long-term effects on users' mental health and general wellbeing.

Collaborations and Collaborations: To advance mental health and well-being on a broader scale, form collaborations with institutions, governments, and organizations.

User-Centric Design: Prioritize user-centric design principles to ensure the app remains intuitive, engaging, and effective for users of all backgrounds and mental health conditions.

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CONCLUSION

In summary, PsychePulse, a machine learning-based mental health assessment tool, represents a major advancement in the use of technology in mental health treatment with its creation and evaluation. By integrating qualitative and quantitative methodologies, the mixed-methods approach made it possible to conduct a thorough evaluation of the app's efficacy. With the use of cutting-edge technology like user input and facial expression analysis, PsychePulse seeks to offer a comprehensive method of mental health screening. The accessibility and usability of the software are improved by the incorporation of user-friendly features including profile management, login, and user registration. According to the initial results, PsychePulse has a high level of user happiness and engagement and is useful for evaluating mental health issues. Nevertheless, more verification and enhancement are imperative to guarantee its enduring influence and efficacy.

REFERENCES

1. Iyortsuun, N.K., Kim, S.H., Jhon, M., Yang, H.J., Pant,S. (2023). A Review of Machine Learning and Deep LearningApproaches on Mental Health Diagnosis. Healthcare (Basel),11(3), 285.
2. Ehiabhi, J., Wang, H. (2023). A Systematic Review ofMachine Learning Models in Mental Health Analysis Basedon Multi-ChannelMulti-Modal Biometric Signals. *BioMed-Informatics*, 3, 193-219.
3. W. H. L. Pinaya, A.Mechelli, and J.R. Sato, "Using deepautoencoders to identify abnormal brain structural patterns inneuropsychiatric disorders: a large-scale multi-sample study,"Human Brain Mapping, vol.40, no.3, pp.944–954, 2018.
4. Y. T. Jo, S.W. Joo, S.H.Shon, H.Kim, Y.Kim, and J.Lee,"Diagnosing schizophrenia with network analysis and a machine learning method," International Journal of Methods inPsychiatric Research, vol.29, no.1, 2020.
5. D.Chauhan and V. Jaiswal, "An efficient data miningclassification approach for detecting lung cancer disease," inProceedings of the 2016 International Conference on Communication and Electronics Systems (ICCES), Coimbatore, India,October 2016.
6. M.Olfson, R.C.Kessler, P.A.Berglund, and E.Lin, "Psychiatric disorder onset and first treatment contact in the UnitedStates and Ontario," American Journal of Psychiatry, vol.155,no.10, pp.1415–1422, 1998.
7. T.I.Mueller, A.C.Leon, M.B.Keller et al., "Recurrenceafter recovery from major depressive disorder during 15 yearsof observational follow-up," American Journal of Psychiatry,vol.156, no.7, pp.1000–1006, 1999.
8. R. B. Rutledge, A.M.Chekroud, and Q. J.Huys, "Machine learning and big data in psychiatry: toward clinical applications," Current Opinion in Neurobiology, vol.55,pp.152–159, 2019.
9. M. I. Jordan and T.M.Mitchell, "Machine learning:trends, perspectives, and prospects," Science, vol. 349, no.6245, pp.255–260, 2015.
10. G.Cho, J.Yim, Y.Choi, J.Ko, and S.-H. Lee, "Reviewof machine learning algorithms for diagnosing mental illness,"Psychiatry Investigation, vol.16, no.4, pp.262–269, 2019.
11. A. Lad, S. Ghosalkar, B. Bane, K. Pagade, and A. Chaurasia, "Machine Learning Based Resume Recommendation System", IJMDES, vol. 1, no. 3, pp. 17–20, May 2022.

Human – Computer Dialogue Systems

Aparna Murkar*, Gajanan P Khapre
Priyanaka Nikam, Radhika Kadam
Assistant Professor
VPM's MPCOE
Velneshwar, Maharashtra
✉ aparna.murkar@vpmmpcoe.org
✉ gajanan.khapre@vpmmpcoe.org
✉ priyanka.nikam@vpmmpcoe.org
✉ radhika.kadam@vpmmpcoe.org

Sanjay N. Jadhav
Department of Computer Emgineering
G M Vedak Institute of Technology
Tala, Maharashtra
✉ sanjaysarthi84@gmail.com

ABSTRACT

Human-computer interaction systems facilitate a natural language-based communication link between humans and computers, finding applications in numerous fields such as network documentation and interactive robotics. These systems are traditionally structured around three core components: Natural Language Understanding (NLU), Dialogue Management (DM), and Natural Language Generation (NLG), each comprising various specialised tasks. Historically, each task within these components has been developed separately, leading to issues such as error propagation and inefficiencies. Recent research has shifted towards integrating multiple tasks within single components or end-to-end models, leveraging the rapid advancement of deep neural network technologies. This paper outlines two pivotal frameworks in contemporary dialogue systems, initially reviews advancements in individual tasks, and then delves into integrated models handling multiple dialogue tasks. We evaluate notable models that combine tasks within NLU or NLG, as well as those that integrate tasks across NLU, DM, and NLG, discussing both their advantages and limitations. It's apparent that integrated or end-to-end models represent a significant direction for the future development of human-computer dialogue systems.

***KEYWORDS** : Human-Computer discourse gadget, Natural language understanding, Dialogue management, Natural language generation, Joint version.*

INTRODUCTION

A human-computer communication system serves as a bridge to facilitate interactions between humans and computers through natural language. Often referred to as spoken dialogue systems, these platforms enable humans to use computers more intuitively, primarily through spoken language.

Dialogue systems can be broadly categorized into two types: goal-oriented dialogue systems and non-goal-oriented systems. In the early 1990s, MIT developed a pioneering goal-oriented dialogue system for automated flight booking, sponsored by DARPA. This system was designed to navigate through conversations, extracting essential booking information such as departure cities and times, similar to other systems like the HMIHY telecommunications service system, the JUPITER weather inquiry system, and the DARPA Communicator travel planning system. These task-specific systems aim to accomplish specific objectives.

Conversely, non-goal-oriented dialogue systems, or chatter bots, engage in conversations without a predefined objective. The first of these, Eliza, laid the groundwork for the modern chatbot. In recent years, chatbots have become increasingly prevalent, often integrated into broader systems like Cortana and Google Now.

The distinction between goal-oriented and non-goal-oriented dialogues is not always clear-cut, as real-world interactions often blend elements of both. For instance, interactions with customer service may shift between casual conversation and goal-oriented tasks, like booking a flight. An effective dialogue system should, therefore, be versatile, supporting both casual and task-specific exchanges.

The demand for consumer robots and virtual assistants is growing, driving advancements in human-computer interaction. Research in this field has led to significant improvements in dialogue system models, algorithms, and performance. The recent surge in computational power, the availability of extensive dialogue corpora, and innovations such as deep neural networks have fueled new developments in dialogue system technology.

This paper focuses on the trend towards integrating multiple tasks within dialogue systems, a key area of recent progress. This paper is structured as follows: Section 2 revisits the architecture of goal-oriented dialogue systems. Section 3 provides an overview of the subtasks within these systems. The main focus, Section 4, discusses recent efforts and advancements in integrating various subtasks in dialogue systems, covering both goal-oriented and non-goal-oriented dialogues. Conclusions are drawn in Section 5.

FRAMES OF GOAL-DRIVEN DIALOGUE SYSTEMS

Fig 1 illustrates a basic framework for a goal-oriented dialogue system, comprising three main components: Natural Language Understanding (NLU), Dialogue Management (DM), and Natural Language Generation (NLG). Users can interact with the system through either speech or text; speech inputs require an Automatic Speech Recognition (ASR) component before NLU, and speech outputs necessitate a Text-To-Speech (TTS) system post-NLG.

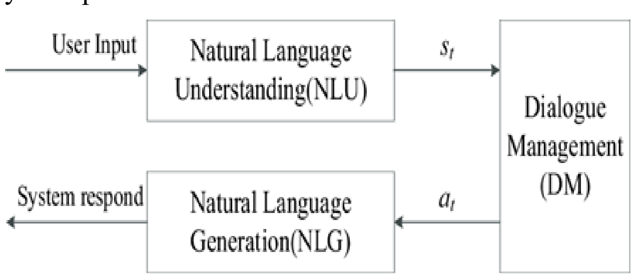


Fig.1. A Basic frame for dialogue system when states are fully observable

NLU's task is to extract relevant details from user inputs, such as identifying cities and flight times in a booking context. DM guides the flow of conversation, typically employing a Markov Decision Process (MDP) to model dialogue states and transitions to achieve the system's goals. NLG then translates DM's decisions into user-friendly responses.

Due to uncertainties introduced by ASR and NLU errors, a more advanced model, the Partially Observable Markov Decision Process (POMDP), is recommended to manage dialogue with higher precision, accommodating the unpredictable nature of user inputs by maintaining a belief state of possible dialogue scenarios based on NLU outputs.

DM strategizes the conversation's progress, selecting actions based on current states to maximise positive outcomes, while NLG formulates these strategies into coherent sentences. Addressing the challenges in NLU, DM, and NLG involves ongoing research to refine these systems' accuracy and user interaction quality.

MODELING EACH SUBTASK SEPARATELY

Traditional human-computer dialogue systems are designed in a linear, pipeline fashion where each subtask is developed independently and then linked together, as illustrated in Figures 1 and 2. Significant efforts have been made to improve the performance of these individual subtasks. This paper briefly mentions these efforts without going into detail. For an in-depth exploration of traditional dialogue systems, especially those based on the POMDP framework, readers are encouraged to consult the detailed reviews by Young, Gasic, Thomson, et al. [6] and Yu, Chen, Chen, et al. [7].

Subtasks in Natural Language Understanding

Natural Language Understanding (NLU) plays a pivotal role in decision-making (DM) by extracting crucial information such as domain, intent, and semantic details from user input. Typically treated as classification problems, domain and intent identification utilize supervised classifiers like Support Vector Machine (SVM), Maximum Entropy (ME), and Deep Neural Networks (DNN), achieving high accuracies, often exceeding 90% in some datasets. However, the scarcity of labelled data in new domains challenges supervised methods, leading to the exploration of less accurate unsupervised approaches.

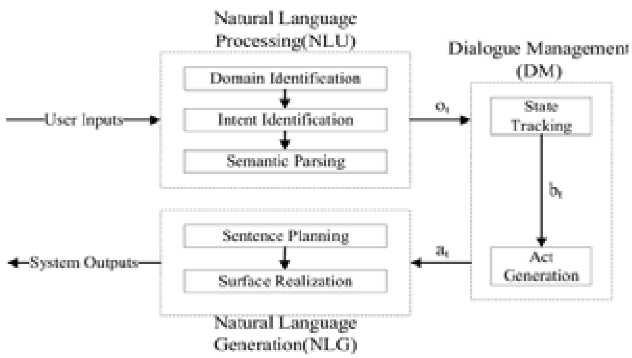


Fig.2 A basic Frame for Human-Computer dialogue systems when states are partially observable.

Slot filling, viewed as sequence labelling, employs models such as Conditional Random Fields (CRF) and Recurrent Neural Networks (RNN), where RNNs generally outperform CRFs, especially in simpler datasets like ATIS. Unsupervised slot filling methods lag behind supervised ones, despite attempts using techniques like Latent Dirichlet Allocation (LDA) and matrix factorization to improve performance. Ongoing research focuses on enhancing unsupervised slot-filling techniques through innovative approaches like graph-based methods.

Subtasks in DM

Dialogue Management (DM) research often explores handling conversations with partially observable states, employing Partially Observable Markov Decision Processes (POMDP) for tasks like state tracking and rule generation. Challenges in updating belief states within POMDP have led to various approximation methods. Experimental results highlight weaknesses in existing methods, pushing towards discriminative models for better performance in tasks like the Dialogue State Tracking Challenge (DSTC). [25] Techniques like deep learning and hybrid models have shown improvements.

Training involves compressing the vast space of possible states using methods like Monte Carlo optimisation and neural networks, with Gaussian support learning techniques enhancing policy control. Stochastic game frameworks have been suggested as alternatives to POMDPs to overcome assumptions about fixed rules and cooperative goals, acknowledging real-world dialogues' complexity where participants may have divergent objectives and strategies.

Subtasks in NLG

Natural Language Generation (NLG) processes input from a Dialogue Manager (DM), determining "what to say" and "how to say it" through sentence construction and lexical choices. It involves lexicalization, selecting words to express concepts, referring expression generation, and choosing phrases for entities. Techniques ensure the correspondence between semantic representation and sentence structure, using schemas for sentence generation and tree-adjoining grammar for syntactic organization. Advanced algorithms like A* search help generate coherent sentences. Despite progress in ensuring syntactic accuracy and consistent spelling, challenges remain in enhancing visual and interactive dialogue [30] components. Further research is needed to improve these aspects of the NLG.

JOINTLY MODELING MULTIPLE SUBTASKS

Traditional conversational systems relied on piped systems, where subtask models were sequentially built and then assembled. Despite their conceptual simplicity, piped systems have limitations. They struggle to leverage interaction data crucial for optimal performance and face challenges in bug identification and error propagation. Interdependencies among subtasks complicate single-task modeling. Ensemble modelling, integrating multiple subtasks into an end-to-end framework, addresses these issues, surpassing the drawbacks of conventional pipelines.

Jointly modeling subtasks in NLU

In recent years, deep learning has made significant strides across various applications, particularly in the realm of Natural Language Understanding (NLU). Researchers such as Xu and Sarikaya have introduced joint models employing Convolutional Neural Networks (CNN), surpassing traditional methodologies. Additionally, Guo, Tur, and Yih proposed a Recursive Neural Network (RecNN) approach, demonstrating competitive performance, while Shi, Yao, and Chen utilised an RNN-based approach with LSTM, achieving impressive results. Moreover, Lee and Ko employed Conditional Random Fields (CRFs) for ensemble modelling, leading to further advancements.

Despite these achievements, challenges persist. Determining the optimal method for joint modelling remains uncertain, and the acquisition of labelled data, especially for supervised models, proves costly. Unsupervised techniques lag behind, raising concerns about their practicality. Domain adaptation poses another obstacle, although solutions such as zero-shot learning show promise.

In conclusion, while ensemble modelling holds potential for enhancing NLU, challenges remain in selecting appropriate modelling techniques, obtaining labelled data, and adapting models across different domains. Continued research and innovation are imperative to fully exploit the benefits of joint NLU models.

Jointly modeling subtasks cross NLU and DM

The integration of semantic tags into Dialogue Management (DM) has progressed, with some methods directly using sentences as input. Henderson, Thomson, and Young proposed an RNN model for state tracking, exhibiting superior performance. Mrksic & Kadlec introduced a multi-domain state tracking model with promising results when combined with delexicalized features.

Reinforcement learning (RL) has become pivotal for dialogue modelling, particularly in ensemble models like action generation. Deep RL (DRL), initially developed for gaming, has found adoption in dialogue systems. Mnih, Kavukcuoglu, and Silver achieved competitive scores with DRL algorithms in gaming environments.

Given the similarities between gaming and dialogue, DRL is increasingly utilized in end-to-end dialogue systems. Cuayahuitl and Keizer experimented with DRL for non-cooperative dialogue using a card game scenario. Zhao and Eskenazi also applied DRL for state tracking and action generation.

However, training Q-function networks for DRL presents challenges due to data scarcity and convergence issues. Techniques like replaying and double DQN have been proposed to address these challenges, but convergence in DRL remains complex, especially with large action spaces in dialogues. Addressing these issues is an important goal for the future.

Joint models for subtasks across NLU, DM and NLG

The idea of jointly modelling all facets of dialogue systems, from understanding user input to generating responses, is attractive for creating truly end-to-end models. However, in task-based scenarios like flight booking, it's crucial for the system to retain and update task-related information throughout the conversation, such as departure time and city. Presently, complete end-to-end models for such tasks are lacking, with most models focusing on specific subtasks. Conversely, for non-task-oriented dialogues like casual conversation, the focus is typically on response generation. Recent advancements in term-driven approaches, particularly those rooted in machine translation, show promise for generating responses.

Some models address data scarcity by integrating contextual information. Sequence-to-sequence models have also been adapted for non-task-based dialogues, incorporating attention mechanisms for improved performance. However, these methods lack semantic analysis and precise dialogue management, limiting their application to task-driven dialogues. To evaluate these systems, various tasks have been proposed, including question-answering and recommendations. Bridging the gap between non-task-driven and task-driven dialogues remains an intriguing challenge. Leveraging advancements in sequence-to-sequence machine translation models could lead to more robust task-based dialogue systems in the future. In conclusion, a comprehensive task-based dialogue system should not only generate responses but also maintain and update internal representations or memories throughout the conversation, either explicitly or through external validation tasks such as question answering.

CONCLUSIONS

Although joint models are in their infancy, they have shown advantages over previous pipeline models. One key benefit is their ability to model interactions among different subtasks within a single framework, enhancing overall system performance. Additionally, joint models can eliminate manually constructed intermediary representations, making dialogue modelling more flexible and adaptable to diverse tasks and domains. It's notable that many recent joint models utilise deep neural networks, offering standardised architectures and training methodologies across subtasks. Reinforcement learning remains central to dialogue management, with recent advancements in deep reinforcement learning driving progress in joint model research. However, numerous challenges remain. These include acquiring sufficient data for model construction, effective training of joint models, and adapting models from one domain to another. Some of these challenges are theoretically intriguing, while others are practically significant, indicating a rich landscape for future research in joint models.

REFERENCES

1. S. Seneff, L. Hirschman, V.W. Zue, Interactive problem solving and dialogue in the ATIS domain, in: Proceedings of the Workshop on Speech and Natural Language, 1991, pp. 354e359. Pacific Grove, California, February 19e22, 1991.
2. A.L. Gorin, G. Riccardi, J.H. Wright, How may I help you? Speech Commun. 23 (1) (1997) 113e127.
3. V. Zue, S. Seneff, J. Glass, et al., JUPITER: a telephone-based conversational interface for weather information, IEEE Trans. Speech Audio Process. 8 (1) (2000) 85e96.
4. M. Walker, J. Aberdeen, J. Boland, et al., DARPA communicator dialog travel planning systems: the June 2000 data collection, in: Proceedings of 2001 European Conference on Speech Communication and Technology, 2001, pp. 1371e1374.
5. J. Weizenbaum, ELIZAda computer program for the study of natural language communication between man and machine, Commun. ACM 9 (1) (1966) 36e45
6. S. Young, M. Gasic, B. Thomson, et al., POMDP-based statistical spoken dialogue systems: a review, Proc. IEEE 101 (5) (2013) 1160e1179
7. M. Henderson, B. Thomson, J. Williams, The second dialog state tracking challenge, in: Proceedings of 2014 Special Interest Group On Dialogue(SIGDIAL) Conference, Association for Computational Linguistics, 2014a, pp. 263e272. Philadelphia, U.S.A., 18e20 June 2014.
8. D. Jurafsky, J.H. Martin, Speech and Language Processing: An Introduction to Natural Language Processing, Computational Linguistics, and Speech Recognition, second ed., Prentice-Hall, 2007.
9. P. Haffner, G. Tur, J. Wright, Optimizing SVMs for complex call classification, in: Proceedings of International Conference on Acoustics, Speech and Signal Processing, Hong Kong, April, 2003, 2003.
10. J. Ang, Y. Liu, E. Shriberg, Automatic dialog act segmentation and classification in multiparty meetings, in: Proceedings of International Conference on Acoustics, Speech and Signal Processing, 2005, 2005.
11. R. Sarikaya, G.E. Hinton, A. Deoras, Application of deep belief networks for natural language understanding, IEEE Trans. Audio, Speech Lang. Process. 22 (4) (2014) 778e784.
12. O. Vinyals, Q.V. Le, A neural conversational model, in: Proceedings of 2015 International Conference on Machine Learning(ICML2015), 2015.
13. A. Ezen-can, K.E. Boyer, Combining task and dialogue streams in unsupervised dialogue act models, in: Proceedings of 2014 Special Interest Group On Dialogue(SIGDIAL) Conference, Association for Computational Linguistics, 2014, pp. 113e122. Philadelphia, U.S.A., 18e20 June 2014.
14. K. Yao, G. Zweig, M. Hwang, et al., Recurrent neural networks for language understanding, Interspeech (2013) 2524e2528.
15. G. Mesnil, Y. Dauphin, K. Yao, et al., Using recurrent neural networks for slot filling in spoken language understanding, IEEE/ACM Trans. Audio Speech Lang. Process. 23 (3) (2015) 530e539.
16. V. Vukotic, C. Raymond, Gravier, et al., Is it time to switch to word embedding and recurrent neural networks for spoken language understanding?, in: Interspeech2015, 2015.
17. L. Shang, Z. Lu, H. Li, Neural responding machine for short-text conversation, in: Proceedings of ACL-IJCNLP, 2015, pp. 1577e1586.
18. G. Tur, A. Celikyilmaz, D.Z. Hakkani-Tur, Latent semantic modeling for slot filling in conversational understanding, in: Proceedings of 2013 IEEE International Conference on Acoustics, Speech and Signal Processing, 2013.
19. Y. Chen, W.Y. Wang, A. Gershman, et al., Matrix factorization with knowledge graph propagation for unsupervised spoken language understanding, in: ACL-IJCNLP2015, 2015, pp. 483e494.
20. I.V. Serban, A. Sordoni, Y. Bengio, et al., Building end-to-end dialogue systems using generative

hierarchical neural network models. http:// arxiv.org/ abs/1507.04808, 2016.

21. O. Dusek, F. Jurcicek, Sequence-to-Sequence generation for spoken dialogue via deep syntax trees and strings, in: Proceedings of the 54th Annual Meeting of the Association for Computational Linguistics, 2016, pp. 45e51. Berlin, Germany.
22. Y. Chen, W.Y. Wang, A.I. Rudnicky, Jointly modeling inter-slot relations by random walk on knowledge graphs for unsupervised spoken language understanding, in: Proceedings of 2015 NAACL-HLT, 2015.
23. H. Mei, M. Bansal, M.R. Walter, What to talk about and how? Selective generation using LSTMs with coarse-to-fine alignment. http://arxiv.org/ abs/1509.00838, 2015.
24. V. Mnih, K. Kavukcuoglu, D. Silver, et al., Human-level control through deep reinforcement learning, Nature 518 (2015) 529e533. Feb 26, 2015.
25. V. Mnih, K. Kavukcuoglu, D. Silver, et al., Playing Atari with deep reinforcement learning, Comput. Sci. (19 Dec 2013) https://arxiv.org/abs/ 1312.5602.
26. T.H. Wen, M. Gasic, N. Mrksic, Semantically conditioned lstm-based natural language generation for spoken dialogue systems, in: Proceedings of Conference on Empirical Methods on Natural Language Processing(EMNLP2015), 2015.
27. T.H. Wen, M. Gasic, D. Kim, et al., Stochastic language generation in dialogue using recurrent neural networks with convolutional sentence reranking, in: Proceedings of 2015 Special Interest Group On Dialogue(SIGDIAL), 2015
28. Y. Ma, X. Wang, A two layer LSTM based deep reinforcement learning for goal-driven dialogue system, BUPT CIST Tech Report, No 20161201, 2016
29. N. Mrksic, R. Kadlex, et al., Multi-domain dialog state tracking using recurrent neural networks, in: Proceedings of 2015 ACL-IJCNLP, 2015, pp. 794e799.
30. B. Lavoie, O. Rambow, A fast and portable realizer for text generation systems, in: Proceedings of the Fifth Conference on Applied Natural Language Processing, ANLC, 1997, pp. 265e268. Washington, DC.
31. P. Xu, R. Sarikaya, Convolutional neural network based triangular crf for joint intent detection and slot filling, in: 2013 IEEE Workshop on Automatic Speech Recognition and Understanding (ASRU), 2013, pp. 78e83.

[32. D. Guo, G. Tur, W. Yih, et al., Joint semantic utterance classification and slot filling with recursive neural networks, in: Proceedings of Spoken Language Technology2014, 2014, pp. 554e559.

33. Y. Shi, K. Yao, H. Chen, et al., Contextual spoken language understanding using recurrent neural networks, in: Proceedings of 2015 IEEE International Conference on Acoustics, Speech and Signal Processing, 2015, pp. 5271e5275
34. Y. Schaul, J. Quan, I. Antonoglou, et al., Prioritized experience replay, arXiv preprint, http://arxiv.org/ abs/1511.05952, 2015.
35. C. Lee, Y. Ko, A simultaneous recognition framework for the spoken language understanding module of intelligent personal assistant software on smart phones, in: Proceedings of 2015 ACL-IJCNLP Conference, 2015, pp. 818e822.
36. H.V. Hasselt, A. Guez, D. Silver, Deep reinforcement learning with double q- learning, arXiv preprint, http:// arxiv.org/abs/1509.06461, 2015.
37. M. Henderson, B. Thomson, S. Young, Word-based dialog state tracking with recurrent neural networks, in: Proceedings of 2014 Special Interest Group On Dialogue(SIGDIAL), 2014.

Role of Natural Language Processing and Deep Learning in Malware Detection: A Review

Ketan Raju Kundiya*
Assistant Professor
VPM's Maharshi Parshuram College of Engineering
and PhD Student COEP Tech. University
Pune, Maharashtra
✉ ketanrkundiya@gmail.com

Yashodhara Haribhakta
Associate Professor
COEP Tech. University
Pune, Maharashtra
✉ ybl.comp@coeptech.ac.in

ABSTRACT

In today's world cyberattacks over the internet, the use of traditional executable files as delivery vehicles for malicious payloads. These executable files have secured their place as the form of email attachments, posing a significant challenge to cybersecurity. Evading detection mechanisms like antivirus software, attackers often employ sophisticated obfuscation techniques to conceal their malware. In this context, pattern-matching-based detection approaches, such as antivirus programs, have proven inadequate for identifying novel and emerging threats. This research presents a comprehensive survey of the state of the art in malware detection, emphasizing the critical role that natural language processing (NLP) techniques play in combating these cyber threats. It explores various research papers, each offering unique insights and methods for malware detection. From applying NLP techniques like Bag of Words (BoW), Word2Vec, and LSI-TF-IDF, to the use of deep learning models such as CNN-LSTM, CNN, RNN, and LSTM, the paper discusses the strengths and limitations of these approaches. Ultimately, this research underscores the efficacy of leveraging NLP techniques in the fight against malware, demonstrating their ability to detect both known and novel threats, and highlights the potential of combining these techniques with deep learning classifiers for robust cybersecurity solutions.

KEYWORDS *: NLP (Natural language porocessing), Malware detection, Cybersecurity, Deep learning.*

INTRODUCTION

Cybersecurity is a pressing concern in today's digital age as the internet has become a fertile ground for targeted attacks, jeopardizing the security of individuals, organizations, and even nations. This introduction sets the stage for our exploration of malware detection, focusing on the critical role that natural language processing (NLP) techniques play in countering this ever-evolving threat landscape [1].

(Fig. 1) shows count of previous ten year research on Malware Detection using NLP from Elsevier, Springer, IEEE, and ACM from the year 2014 onwards including journals and conferences.The Fig.1 illustrates that a significant portion of research in this field has been conducted post-2018.

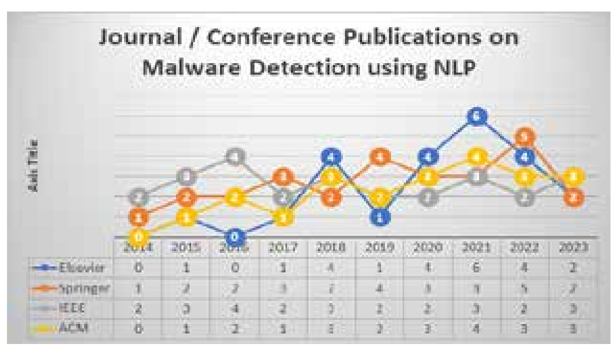


Fig. 1: Last 10 year publications on Malware detection using NLP

The Resilience of Traditional Executable Files

Despite the ongoing evolution of cyber threats, traditional executable files continue to serve as a popular and effective payload for these malicious attacks [1][19][21]. These files can execute various actions on a victim's computer, making them a versatile tool for cybercriminals.

The Prevalence of Malicious Email Attachments

A concerning trend in the world of cyberattacks is the prevalence of malicious email attachments. According to a recent report, executable files rank as the second most common type of malicious email attachment. This statistic underscores the significance of addressing the threat posed by executable files to enhance email security.

The Art of Obfuscation

To traditional cybersecurity defenses, attackers have become increasingly adept at concealing their malicious intent. They employ obfuscation techniques, which involve disguising the true nature of malware to make it harder for antivirus programs to detect. There is the need for more advanced detection methods.

The Limitations of Pattern Matching-Based Detection

Traditional antivirus programs primarily rely on pattern matching-based detection methods. These programs compare files to known patterns of malware to identify threats. However, this approach has a critical limitation: it struggles to detect new and previously unseen malware. As attackers continuously evolve their tactics, relying solely on pattern matching becomes increasingly ineffective.

There are various types of malware attacks that cybersecurity experts and organizations face in today's digital landscape:

Different Malware Threats

Malware, means malicious software, there includes a wide range of digital threats [2][18].

Malvertising: Malicious advertising that delivers malware to users via online ads, often without their knowledge.

Cryptomining (Cryptojacking): Illicit use of a victim's computing power to mine cryptocurrency for the attacker's benefit.

Spyware: Software that secretly monitors a user's activities, collecting sensitive information without consent.

Adware: Unwanted software that bombards users with intrusive advertisements.

Ransomware: Malware that encrypts a victim's files and demands a ransom for decryption.

Trojans: Deceptive software that appears legitimate but carries malicious payloads, such as backdoors or spyware.

Worms: Self-replicating malware that spreads across networks or systems.

Rootkits: Malicious software that hides deep within an operating system, making it difficult to detect and remove.

Backdoors: Hidden entry points in a system that allows unauthorized access to cybercriminals.

Fig. 2: Various types of Malware Attacks

These diverse forms (shown in Fig. 2) of malware attacks pose significant threats, each with its unique characteristics and methods of attack. As the malware landscape continues to evolve, addressing these threats becomes increasingly challenging [16][17].

The Role of Natural Language Processing (NLP)

In the face of these multifaceted cyber threats, NLP emerges as a powerful ally in the quest for effective malware detection. NLP, a branch of artificial intelligence, focuses on enabling computers to understand and interpret human language [11][12]. While traditionally applied in fields such as natural language understanding and machine translation, NLP has found a new role in the realm of cybersecurity.

NLP techniques gives cybersecurity experts to analyze and interpret various forms of textual data, which can provide critical insights into the behavior and intent of potential malware. By harnessing the capabilities of NLP, researchers and defenders aim to bolster their ability to identify and mitigate evolving cyber threats.

PROBLEM DEFINITION

Malware detection in executable files is difficult due to obfuscation techniques used to avoid anti-virus programs. Dynamic analysis of all suspicious files from the internet is time-consuming, so a fast filtering method is required. Need of develop a method that is effective in detecting not only existing malware but also new and packed malware with anti-debugging techniques.

LITERATURE REVIEW

According to surveyed literature, it is found that NLP (Natural Language Processing) is emerging as very effective for malware detection by using the NLP techniques of Bag of Words (BoW), Word2Vec, and LSI-TF-IDF with deep learning models such as CNN, RNN, LSTM. Mimura and Ito [1] explored the application of Natural Language Processing (NLP) techniques to enhance malware detection in practical environments. They employed NLP methods such as Printable strings with Bag of Words (BoG), Word2Vec, and Latent Semantic Indexing (LSI) combined with Term Frequency-Inverse Document Frequency (TF-IDF). The approach showed promise in detecting both existing and new malware variants, demonstrating its effectiveness. However, it had limitations, including challenges in packer detection precision, reliance on an imbalanced dataset, and constraints due to limited training data.

Akhtar and Feng [2] focused on malware detection using deep learning techniques, specifically Convolutional Neural Networks (CNN) and Long Short-Term Memory (LSTM). Their approach achieved remarkable detection accuracy of 99%. However, it didn't consider the semantics of raw binary files, potentially missing important behavioral aspects of malware.

Zhang et al. [3] introduced a hybrid sequence-based approach for Android malware detection utilizing static opcode and dynamic system call sequences. They employed a CNN-BiLSTM-Attention classifier, achieving a detection accuracy of 97%. However, it's essential to note that their study primarily focused on the Android environment, limiting its generalizability.

Karbab and Debbabi [4] formulated behavioral reports for malware detection using a Bag of Words (BoW) NLP model. Their method achieved a detection accuracy of 94% and exhibited versatility by being effective on various platforms, including Android and Win32. Nevertheless, its performance could be influenced by the execution environment.

Yeboah and Musah [5] employed a one-dimensional Convolutional Neural Network (1D CNN) fusion model for Android malware detection. Their approach demonstrated a high detection accuracy of 97% by extracting features from semantically embedded n-grams of raw static opcode sequences. However, it focused exclusively on the Android environment and required constant updates upon deployment.

Khan et al. [6] explored lightweight deep learning solutions for malware detection in IoT-constrained environments, utilizing Recurrent Neural Networks (RNN), Long Short-Term Memory (LSTM), and Bidirectional LSTM (Bi-LSTM). Their approach achieved an impressive accuracy score of up to 99.45% but primarily focused on the IoT environment, potentially limiting its applicability elsewhere.

Poudyal et al. [7] developed a multi-level ransomware detection framework using NLP and machine learning. Their method applied n-gram Term Frequency-Inverse Document Frequency (TF-IDF) on DLL, function call-opcode, and assembly instructions, reaching a high detection accuracy of 98.59%. However, the study would benefit from incorporating deep learning methods and testing on a broader range of datasets.

Garg and Yadav [8] utilized supervised learning algorithms for malware detection based on the frequency of API calls, with feature selection using Random Forest (RF). Their approach achieved an accuracy score of up to 93%. Nevertheless, it solely relied on API calls, and unsupervised or semi-supervised techniques were not explored.

Lu [9] conducted malware detection using Long Short-Term Memory (LSTM) networks, with a specific focus on the analysis of opcodes. The LSTM-based method exhibited an accuracy score of up to 98%, showcasing its capability to identify malware based on opcode language. However, it focused exclusively on opcodes, potentially missing other behavioral aspects of malware.

Kim [10] employed n-gram Term Frequency-Inverse Document Frequency (TF-IDF) on system calls for malware detection, primarily focusing on native API system calls. The method achieved an accuracy score of up to 96% in detecting malware based on API system calls. Similar to other studies, its focus on a specific aspect (API system calls) may limit its coverage of malware behavior.

Manning and Schütze's work on "Foundations of Statistical Natural Language Processing" [12] lays the groundwork for understanding statistical methods in natural language processing, providing valuable insights into the application of these techniques in the context of malware analysis.

The National Institute of Standards and Technology (NIST) Computer Security Resource Center [13] is a crucial resource for establishing and maintaining standards in computer security, serving as a foundational reference for best practices and guidelines in the field. Ligh et al.'s "Malware Analyst's Cookbook: Tools and Techniques for Fighting Malicious Code" [14] is an essential reference that provides practical tools and techniques for malware analysts, offering valuable insights into the hands-on aspects of combating malicious code.

The SANS Institute [15] is a reputable organization that plays a pivotal role in cybersecurity training and education. Their contributions and resources are invaluable for professionals seeking to enhance their skills in malware analysis and defense.

Szor's "The Art of Computer Virus Research and Defense" [16] is a seminal work that delves into the intricate details of computer virus research, providing comprehensive insights into the methodologies and strategies for defending against malicious code.

The US-CERT (United States Computer Emergency Readiness Team) [17] serves as a central hub for cybersecurity information and incident response. Their resources are instrumental in staying informed about current threats and vulnerabilities.

Skoudis and Zeltser's "Malware: Fighting Malicious Code" [18] is a noteworthy resource that addresses the multifaceted aspects of malware, offering comprehensive coverage of strategies and techniques to combat malicious code effectively. Kolter and Maloof's research on "Learning to detect malicious executables in the wild" [19] contributes significantly to the field of machine learning applied to malware detection, providing a foundation for developing intelligent systems to identify malicious behavior.

Goldberg's "Neural Network Methods for Natural Language Processing" [20] is a contemporary resource that explores the application of neural network methods in natural language processing, offering insights into the potential of these techniques in the context of malware analysis.

Sahay and Sharma's work on "Grouping the Executables to Detect Malwares with High Accuracy" [21] presents a methodological approach to malware detection, emphasizing the importance of executable grouping for achieving high accuracy in identifying malicious code.

These research papers collectively contribute to the understanding of various methodologies and their effectiveness in the malware detection, showcasing both strengths and limitations in the application of NLP and machine learning techniques.

SYSTEM ARCHITECTURE

The working process detecting malware using NLP is shown in (Fig. 3.) The dataset is first chosen in order to train the NLP model. To train and test an NLP model at the data layer, this dataset is split into training and testing datasets. The training dataset is then given to a language model. Currently, Doc2Vec is the state-of-the-art language model; it is trained on the entire document at once, typically using embeddings. In a similar vein, Word2Vec uses transformers to train on the individual word bag. To capture the innate semantics of the material, standard Latent Semantic Indexing (LSI) is also available. These models are assessed using the testing dataset, which is not visible, and trained using the training dataset. Lastly, the clean and contaminated data are classified using a trained model. Based on a specific dataset or topic, the best-performing classifier is selected. These classifiers frequently employ deep learning and machine learning methods. Further results are evaluated by various evaluation matrix

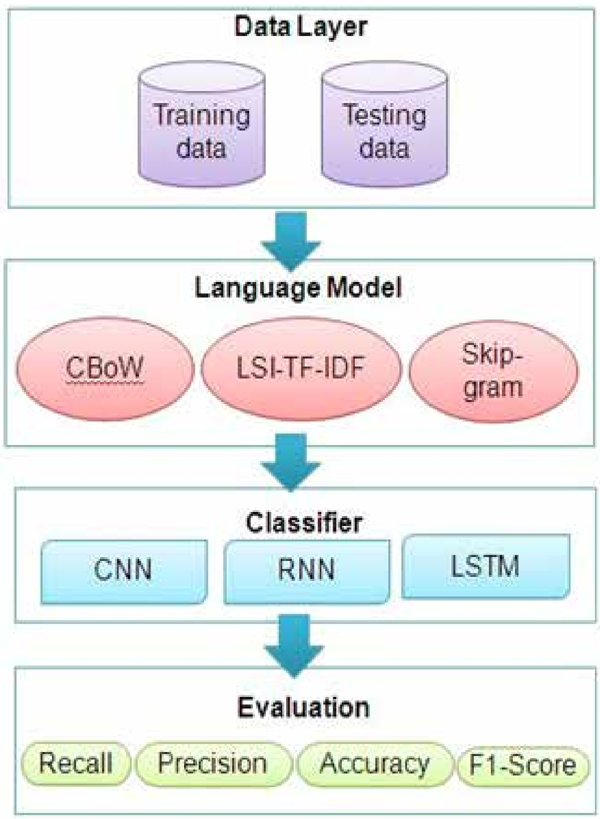


Fig. 3: NLP Based Malware Detection Model

RESULT AND DISCUSSION

The (Table 1) presents a summary of notable research papers on malware detection, including the authors' names, publication years, detection accuracy percentages, methods and techniques employed and limitations mentioned. The publication years of the papers range from 2018 to 2022, indicating recent developments in the field of malware detection. Detection accuracy percentages vary across the papers, with values ranging from 90% to 99.45%. This suggests that different methods and techniques have been effective to varying degrees in detecting malware. Various methods and techniques have been employed, including natural language processing (NLP), deep learning, CNN-LSTM, n-gram TF-IDF, and LSTM, indicating a diversity of approaches in the research.

The highest reported detection accuracy in the table is 99.45%, achieved by Khan et al. [6] using RNN, LSTM, and Bi-LSTM. This suggests that deep learning techniques have shown remarkable effectiveness in malware detection. Akhtar et al. [2] achieved a high accuracy of 99% using CNN-LSTM, indicating the success of convolutional and recurrent neural networks in real-time malware detection. Several papers, such as Mimura et al. [1], Zhang et al. [3], and Yeboah et al. [5], also achieved relatively high detection accuracy, demonstrating the potential of various NLP and deep learning techniques.

(Table 1) provides a comprehensive overview of various scholarly works related to malware detection using NLP, focusing on key aspects such as the publication reference, year, detection accuracy percentage, methods/techniques employed, and identified limitations. Its offering insights into the evolution of malware detection strategies using NLP and their respective effectiveness.

Table 1: A comprehensive overview of various scholarly works

Reference	Year	Detection Accuracy (%)	Methods/Techniques	Limitations
Mimura et al. [1]	2022	90	Printable Strings, BoG, WordToVect, LSI - TF-IDF	Packer Detection Precision, Imbalanced dataset, Limited training data
Akhtar et al. [2]	2022	99	CNN-LSTM	Raw binary semantics not considered

Zhang et al. [3]	2021	97	CNN-BiLSTM-Attention	Focuses on Android environment
Karbab et al. [4]	2019	94	Bag-of-words (BoW) NLP	Performance affected by execution environment
Yeboah et al. [5]	2022	97	1D CNN	Focuses on Android environment, requires constant updates
Khan et al. [6]	2022	99.45	RNN, LSTM, Bi-LSTM	Focuses on IoT environment
Poudyal et al. [7]	2019	98.59	n-gram TF-IDF	Could benefit from deep learning methods, more datasets needed
Garg et al. [8]	2019	93	Supervised learning using API Calls, RF feature selection	Only uses API calls, lacks unsupervised and semi-supervised techniques
Lu [9]	2019	98	LSTM	Only uses opcodes
Kim [10]	2018	96	n-gram TF-IDF on System Calls	Only uses API System calls

CONCLUSION

In summary, the field of malware detection has greatly benefited from the integration of Natural Language Processing (NLP) techniques. NLP has proven to be a strong tool in the ongoing battle against cyber threats. NLP plays a vital role in malware detection by enabling the analysis of textual and code-based content associated with potential threats. Through techniques such as CBOW Model, TF-IDF, and Skip-gram, NLP helps extract meaningful features and patterns that aid in identifying malicious intent. It provides the capability to understand the context and semantics of textual data, which is crucial in recognizing both known and emerging malware variants. NLP empowers the detection of not only existing malware strains but also new and previously unseen threats. Its adaptability and ability to uncover subtle behavioral indicators make it an invaluable asset in proactively identifying evolving cyber threats. NLP-driven models can adapt to changing attack techniques and identify anomalies indicative of novel malware strains.The combination of NLP techniques with deep learning classifiers such as CNN, RNN, and LSTM has proven to be a good approach in malware detection. These synergistic combinations allow for the comprehensive analysis of diverse data sources, including opcode sequences, system calls, and binary representations. The fusion of NLP and deep learning enhances the accuracy and effectiveness of malware detection systems.

FUTURE WORK

There is need of cross-platform malware detection methods that can generalize across diverse environments, the integration of complementary techniques into unified frameworks, development of real-time detection systems with low latency, emphasis on feature extraction and selection, enhancement of interpretability in deep learning models, and robustness against evolving evasion techniques. We should also focus on addressing imbalanced datasets, ethical considerations, and standardized benchmarks for fair evaluations, along with strategies for automated model updates to adapt to emerging.

REFERENCES

1. Mimura, Mamoru, and Ryo Ito, Applying NLP techniques to malware detection in a practical environment. International Journal of Information Security, 21(2), 279-291. (2022).

2. Akhtar, Muhammad Shoaib, and Tao Feng, Detection of malware by deep learning as CNN-LSTM machine learning techniques in real time. Symmetry, 14(11), 2308. (2022).
3. Zhang, Nan, et al., Hybrid sequence-based Android malware detection using natural language processing. International Journal of Intelligent Systems, 36(10), 5770-5784. (2021).
4. Karbab, ElMouatez Billah, and Mourad Debbabi, MalDy: Portable, data-driven malware detection using natural language processing and machine learning techniques on behavioral analysis reports. Digital Investigation, 28, S77-S87. (2019).
5. Yeboah, Paul Ntim, and Haruna Balle Baz Musah, NLP technique for malware detection using 1D CNN fusion model. Security and Communication Networks, (2022).
6. Khan, Abdur Rehman, et al., Exploring Lightweight Deep Learning Solution for Malware Detection in IoT Constraint Environment. Electronics, 11(24), 4147. (2022).
7. Poudyal, Subash, et al., A multi-level ransomware detection framework using natural language processing and machine learning. 14th International Conference on Malicious and Unwanted Software" MALCON. (2015).
8. Garg, Vidhi, and Rajesh Kumar Yadav, Malware detection based on API calls frequency. 2019 4th International Conference on Information Systems and Computer Networks (ISCON). IEEE. .(2019).
9. Lu, Renjie., Malware detection with LSTM using opcode language. arXiv preprint arXiv:1906.04593. (2019).
10. Kim, Chan Woo., Ntmaldetect: A machine learning approach to malware detection using native API system calls. arXiv preprint arXiv:1802.05412. (2018).
11. Jurafsky, Daniel, and Martin, James H., "Speech and Language Processing: An Introduction to Natural Language Processing, Computational Linguistics, and Speech Recognition." Pearson, (2020).
12. Manning, Christopher D., and Schütze, Hinrich., "Foundations of Statistical Natural Language Processing." MIT Press, (1999).
13. National Institute of Standards and Technology (NIST) Computer Security Resource Center. (https://csrc.nist.gov/)
14. Ligh, Michael, et al., "Malware Analyst's Cookbook: Tools and Techniques for Fighting Malicious Code." Wiley, (2010).
15. The SANS Institute. (https://www.sans.org/)
16. Szor, Peter. "The Art of Computer Virus Research and Defense." Pearson Education, (2005).
17. US-CERT (United States Computer Emergency Readiness Team). (https://www.us-cert.gov/)
18. Skoudis, Ed, and Lenny Zeltser., "Malware: Fighting Malicious Code." Prentice Hall, (2004)
19. Kolter, J. Zico, and Maloof, Marcus A., "Learning to detect malicious executables in the wild." Journal of Machine Learning Research 9 2721-2744. (2008):
20. Goldberg, Yoav. "Neural Network Methods for Natural Language Processing., " Synthesis Lectures on Human Language Technologies, (2017).
21. Sahay, S.K.; Sharma, A., Grouping the Executables to Detect Malwares with High Accuracy. Procedia Comput. Sci., 78, 667–674. (2016)

Spam SMS Detection for Preventing Online Frauds using Machine Learning Algorithms

Ketan Raju Kundiya*
Assistant Professor
VPM's Maharshi Parshuram College of Engineering
and PhD Student COEP Tech. University
Pune, Maharashtra
✉ ketanrkundiya@gmail.com

Yashodhara Haribhakta
Associate Professor
COEP Tech. University
Pune, Maharashtra
✉ ybl.comp@coeptech.ac.in

ABSTRACT

Dealing with internet fraud is a difficult task in the modern world, particularly in light of the increase in dubious Short Message Service (SMS) messages that include dangerous links. The goal of this research is to address this problem by utilizing machine learning (ML), particularly in the area of fraudulent SMS detection. These SMS includes lottery scams, fake offers, phishing links etc. This paper aims to study various machine learning algorithms to determine the best means of spotting spam and ham SMS message classification. SMS Spam Collection Dataset of UCI Machine Learning is used for examine the performance of ML algorithms. The results were evaluated using various algorithms, among which K-NN and Naive Bayes demonstrated 100% precision, with 90% and 97% accuracy, respectively. Random Forest and Support Vector Classifier gives highest accuracy rate of 97.58%.

KEYWORDS *: Short message service, Machine learning, Naïve bayes, Random forest, Support vector Classifier.*

INTRODUCTION

An rising number of people consider their mobile phones to be their constant companions. With millions of people sending messages daily and mobile devices becoming more widely used, Short Message Service (SMS) has grown to be a multi-million dollar commercial industry. The market for short message service (SMS) marketing was estimated to be worth USD 64.5 billion in 2021 and is expected to grow at a compound annual growth rate (CAGR) of 3.8% from 2022 to USD 84.9 billion by 2027 [1]. But the drawback of the rise in mobile phones are drawing in an increasing number of unsolicited bulk messages, particularly in the form of lottery scams, fake offers, phishing links, advertisements.

In the USA, the average number of spam messages received each month per individual rose by 15% in 2022 compared to the previous year. A whopping 8.8 billion dollars was lost to various forms of fraud as a result of phone scams, which affected 68.4 million peoples [2] [3].

SMS is a platform for communication that lets users send and receive brief text messages between mobile devices and fixed lines [4]. Even with its ease of use, unsolicited emails, or spam, continue to appear in our correspondence. Spammers spread these SMS spams, disguised as junk mail, to a wide audience in big quantities. Businesses usually use these spams to market and promote their goods and services. SMS spams are more than just advertisements; they are dangers to consumers' privacy that can result in text-based fraud, identity theft, and phishing assaults [5].

Machine learning is becoming more and more popular in the research community for classification tasks. When it comes to accurately detecting or filtering spam characteristics inside SMS messages, the use of suitable machine learning techniques becomes imperative due to the SMS message corpus's constant growth in size and complexity [6][7][8].

Therefore, the goal of this study is to use the best fitting machine learning method to address the problem of

SMS spam message identification with high precision and accuracy.

RELATED WORK

Content-based solutions employed in email spam filtering can be deployed to prevent the proliferation of mobile phone spams, given the similarities between SMS and email spam [10, 11]. Nevertheless, SMS spams differ from email spams in a few key ways, mostly because typical text messages are limited to 140 characters [12]. As a result, there are a lot less features available for classifying SMS spam than there are for email spam. Because of these limitations, mobile phone spammers frequently use less formal language, acronyms, or idioms. Notwithstanding these distinctions, people may find SMS spams to be equally, if not more, annoying because they may have to pay for the messages they receive [5, 13, 14]. Recipients may suffer financial losses as a result. However, the purpose of sending spam email and SMS—is usually to advertise a business, pull pranks, or commit other fraudulent acts. It's crucial to remember that SMS spams have a different format than email spams, with limitations on the quantity and arrangement of data because of the restricted character set (e.g., alphabets, integers, and symbols). SMS spams don't have headers or headlines in their constrained feature presentation within text messages, in contrast to email spams [13]. Gupta, Suparna Das et al. [9] proposed spam detection techniques with use of TF-IDF vectorizer algorithm. It gives accuracy 95.9% for detecting SMS spam. It used all features of word that poses spam messages. Sjarif, Nilam Nur et al. [7] used Random Forest algorithm with TF-IDF vectorizer algorithm which outperforms other algorithms with accuracy 98.5%.

K-Nearest Neighbour

The k-NN algorithm is a straightforward yet powerful classification technique. A data point is classified according to the feature space's k nearest neighbors' majority class. After calculating the distances between each training example and the data point, the algorithm chooses the k examples that are closest to the data point and assigns the majority class to it. K-NN is a flexible technique that is frequently used for pattern recognition and anomaly detection, although it is sensitive to outliers and necessitates careful tweaking of the k value. It provides a simple method for classifying tasks and is extensively used in many different fields, such as recommendation systems, picture recognition, and spam detection.

Training dataset with labeled examples:

$$D = \{(x_1, y_1), (x_2, y_2), \ldots, (x_n, y_n)\} \quad (1)$$

Where, x_i is the feature vector of the i-th SMS and y_i is its corresponding label (spam or ham)

$$\text{Distance}(x_i, x_{test}) = \sqrt{\sum_{j=1}^{d} (x_{ij}, x_{testj})^2} \quad (2)$$

Where,

x_{test} is feature vector

d is the dimensionality of the feature vectors.

Naive Bayesian

A popular probabilistic classification approach for text categorization, including spam detection, is Naive Bayes. Based on the frequency of specific terms, it determines if a message is spam or not. Though it makes the "naive" assumption that features are independent of one another, it is computationally efficient and works well in practice. When it comes to spam SMS identification, Naive Bayes evaluates the chance that particular terms will appear in messages and uses posterior probabilities to classify messages. Its simplicity, effectiveness, and speed make it a popular choice for different natural language processing jobs, especially in email and text categorization.

$$P(\text{spam} \mid x_{test}) \propto P(\text{spam}) \prod_{i=1}^{m} P(x_{test\,i} \mid \text{spam}) \quad (3)$$

$$P(\text{not-spam} \mid x_{test}) \propto P(\text{not-spam}) \prod_{i=1}^{m} P(x_{test\,i} \mid \text{not-spam}) \quad (4)$$

Random Forest

The random forest algorithm, a prominent machine learning technique, is based on the decision tree concept. Increasing the number of decision trees in a forest increases the accuracy of detection. In order to construct individual trees, this approach uses the bootstrap technique, which involves randomly choosing features and samples with replacements. It determines which splitter among the chosen characteristics is most effective for categorization by using techniques similar to decision trees, such as information gain and gini index. Until the algorithm generates the desired number of trees (n), this process is repeated. Every tree makes a prediction about the target value, and the algorithm counts the votes for each forecast, taking into account the target with the highest number of votes as the final prediction. Following expression represents the average prediction of N individual decision trees in the Random Forest

$$Y(x) = \frac{1}{N} \sum_{i=1}^{N} T_i(x) \qquad (5)$$

Support Vector Classifier

An effective supervised learning approach for regression and classification problems is the Support Vector Classifier (SVC). It operates by identifying the hyperplane that maximizes the margin and most effectively divides data points of various classes. SVC handles non-linear data through the application of kernel functions, mapping input data into higher-dimensional spaces. SVC provides robustness against outliers by locating support vectors, which are data points essential for determining the decision boundary. This technique works well in high-dimensional environments and exhibits adaptability in a variety of fields, such as text categorization and image recognition. SVC is widely used in machine learning because of its capacity to manage complex relationships and optimize decision bounds.

PROPOSED MODEL

In proposed methodology, shown in Fig. 1 Initially, SMS inputs are gathered for the purpose of preprocessing data, which involves cleaning and formatting the dataset. The next step is quantifying the significance of terms through feature extraction and selection using Term Frequency-Inverse Document Frequency (TF-IDF). ML Classifiers K-Nearest Neighbors (KNN), Naive Bayes (NB), Random Forest (RF), and Support Vector Classifier (SVC), are employed for model building. The result indicates if an SMS is a ham or spam. The models are evaluated based on performance criteria such as accuracy, precision are utilized to assess the models' effectiveness in combating online frauds.

Fig. 1: Proposed Architecture

Dataset

SMS Spam Collection Dataset of UCI Machine Learning is used for this research. This dataset includes spam and ham messages.The dataset was collected from Kaggle [15]. It includes a single collection of 5,574 English SMS messages that have been classified as either spam or ham (authentic). Authentic messages are labelled as "ham" and spam messages are labelled as"spam".

Data Cleaning

In the data cleaning process unwanted columns were examined, and the final three ('Unnamed: 2', 'Unnamed: 3', and 'Unnamed: 4') were eliminated. Next, the column names were changed to make more sense: "v1" became "target," and "v2" became "text." After that, duplicate and missing values were eliminated.

Text Preprocessing

A number of crucial actions were completed during the data preprocessing stage in order to improve the text data's quality. Initially, every text was changed to lowercase to make the dataset consistent. After that, tokenization was done to separate phrases into their component words so that more analysis could be done. Stopwords, punctuation, and special characters were methodically eliminated, simplifying the text for insightful examination. The technique of stemming and lemmatization contributed to standardizing word forms, reducing inflected words to their base or root forms. Finally, stopwords had to be removed in order to concentrate on words that carried information. Together, these preprocessing procedures turned the unstructured material into a polished and organized format, setting the stage for reliable text analysis and machine learning applications.

Exploratory Data Analysis

Exploratory Data Analysis (EDA) involves in-depth analysis of the dataset, visualizing patterns, and extracting insights to inform feature selection. It's very crucial for selection of best classification model.

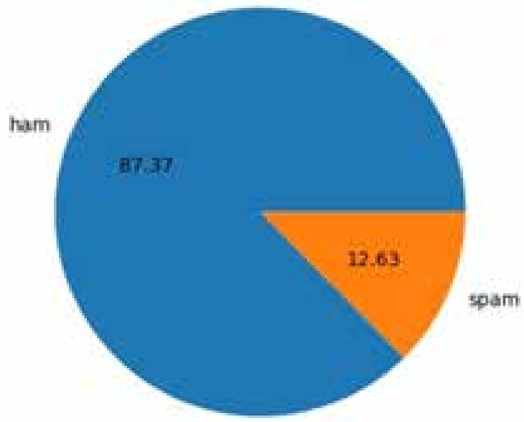


Fig. 2: Percentage of spam and ham sms

The pie chart in Fig 2 shows 87.37% ham and 12.63% spam SMS, reveals a significant data imbalance. It highlights the necessity for precision improvement and a reduction in False Positive Rates (FPR) in spam SMS detection. As imbalanced datasets can skew model performance metrics, addressing this imbalance becomes crucial for achieving more accurate and reliable results in identifying spam messages.

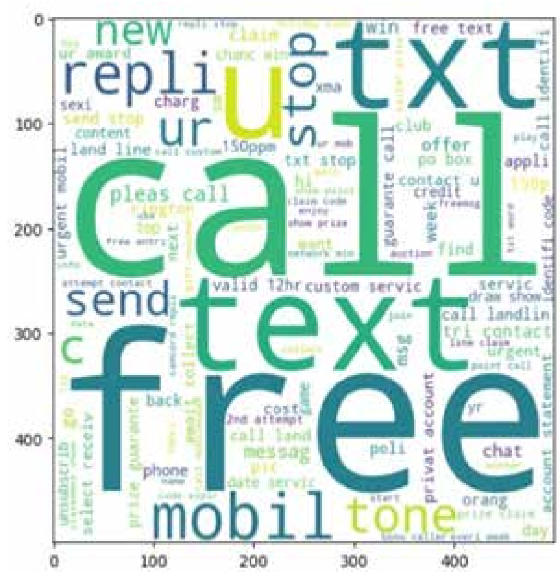


Fig. 3: Word cloud for spam SMS

In above Fig.3, Word cloud spam SMS is represented by highlighted words such as "call", "free," "text," and "mobil" etc. to highlight common spam indicators.

Fig. 4: Word cloud for ham SMS

The above Fig. 4 shows word cloud of ham SMS by highlighting words such as "go," "come," "want," "one," and "need, etc. " thereby exhibiting typical, non-spam language patterns.

The following chart in Fig.5 & 6 shows the top 30 terms in spam and ham SMS, providing information on common vocabulary differences.

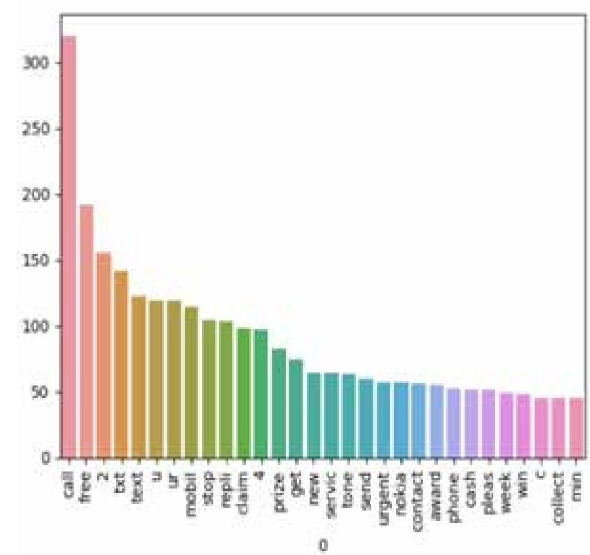


Fig. 5: Top 30 spam words

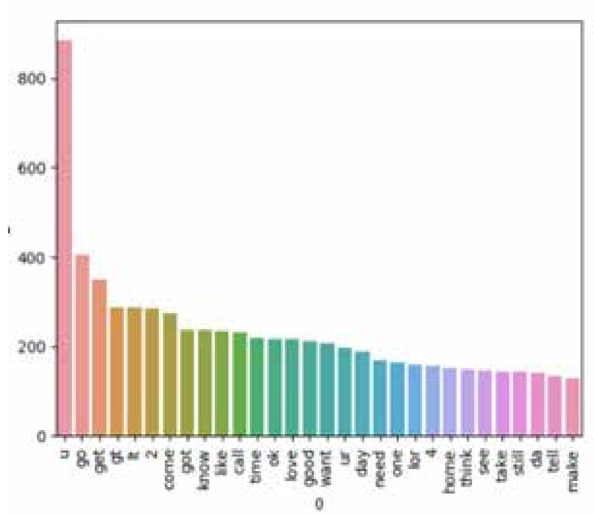


Fig. 6: Top 30 ham words

Feature Extraction and Selection

In order to detect spam SMS, one popular feature extraction method is TF-IDF (Term Frequency-Inverse Document Frequency) [7]. It evaluates a word's significance in a document by taking into account both how frequently it appears in the document and how uncommonly it occurs throughout the dataset. Whereas IDF evaluates a term's originality throughout the entire corpus, TF counts how frequently a term appears in a particular SMS. Higher weights are given to terms that are common inside a document but uncommon overall by the product of TF and IDF. By providing a numerical representation, machine learning algorithms are better able to discriminate between spam and non-spam messages in SMS datasets. This helps identify important phrases.

$$\mathrm{TF-IDF}(t,d,D) = \mathrm{TF}(t,d) \times \mathrm{IDF}(t,D) \quad (6)$$

Where,

TF(t,d) is the Term Frequency of term t in document d.

IDF(t,D) is the Inverse Document Frequency of term t in the dataset D.

Due to the unbalanced data set, extracting new features is essential for strong model training. Adding features such as character, word, sentence count in each SMS improves model sensitivity and flexibility to different message formats, overcoming the data imbalance problem.

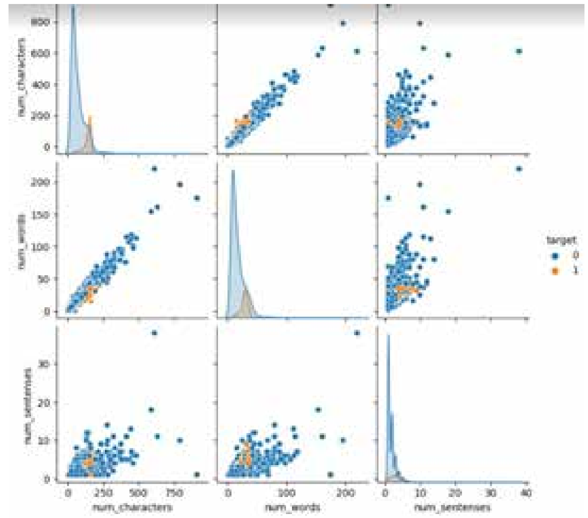


Fig. 7: Pair plot depicted relationship among character, word, sentence count in each SMS

Above Fig. 7 of pair plot shows the visualize relationships and identify outliers among character, word, and sentence counts in spam SMS detection. It also helps in exploring correlations and calculating coefficients for refined analytics.

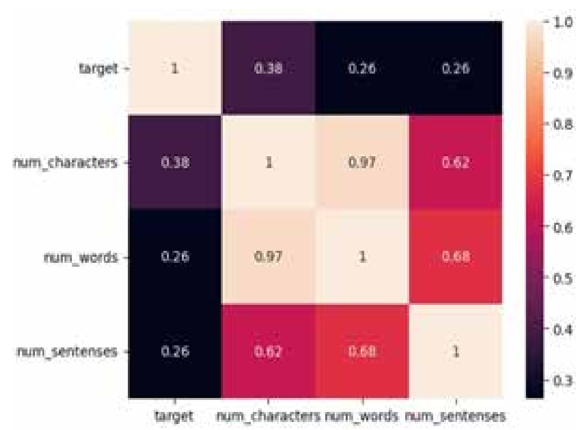


Fig. 8: Heatmap shows correlation between target sms and character, word, sentence count

Examining the relationship between the target text and attributes like character, word, and sentence counts is essential in the context of spam identification. 'num_characters' has a substantial connection of 0.38 with the target, according to the above Fig. 8 of heatmap and correlation matrix. To prevent multicollinearity problems, just 'num_characters' is chosen for model development.

THE EVALUATION AND RESULTS

The spam SMS model was trained and tested using various ML models such as K-Nearest Neighbors, Naive Bayes, Random Forest, Support Vector Classifier, Extra Trees Classifier, Logistic Regression, Adaptive Boosting, Gradient Boosting Decision Trees, Bagging Classifier, and Decision Tree. The ratio in which we split the train and test dataset is 80:20. K-NN and Naive Bayes demonstrated 100% precision, with 90% and 97% accuracy, respectively. Random Forest and Support Vector Classifier gave the highest accuracy rate of 97.58%. Following table describes detailed analysis of performance evaluation of various ML algorithms

Table 1: Performance evaluation of various ML algortihms

Algorithm	Accuracy	Precision
KNN	0.90522	1.00000
NB	0.970989	1.00000
RF	0.975822	0.982906
SVC	0.975822	0.974790
ETC	0.974855	0.974576
LR	0.958414	0.970297
AdaBoost	0.960348	0.929204
GBDT	0.946809	0.919192
BgC	0.958414	0.868217
DT	0.930368	0.817308

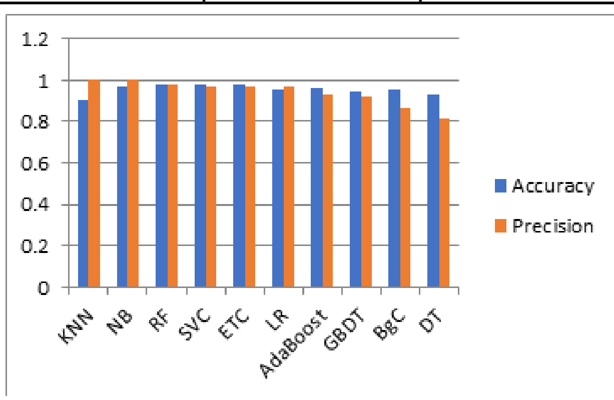


Fig. 9: Evaluation measure of various ML algorithms

CONCLUSION AND FUTURE SCOPE

This research paper tackles the difficult problem of combating online fraud, concentrating on the rise in fraudulent Short Message Service (SMS) texts that contain harmful links. The aim is to utilize machine learning (ML) for the purpose of efficiently detecting fraudulent SMS messages, which include phishing URLs, false offers, and lottery scams. Our research assesses many machine learning (ML) algorithms using the SMS Spam Collection Dataset from UCI Machine Learning in order to identify the best approaches for categorizing spam and ham SMS messages. When training and testing with an 80-20 split of the data, K-NN and Naive Bayes both achieved 90% and 97% accuracy at 100%, respectively, indicating impressive precision. Interestingly, at 97.58%, Random Forest and Support Vector Classifier showed the best accuracy, demonstrating their efficacy in thwarting fake SMS messages.

Future research can investigate deep learning, feature engineering, and advanced natural language processing. Real-time updates and collaborations with telecom providers improve the efficacy and adaptability of the system.

REFERENCES

1. Research and Markets February 03, 2023. https://www.researchandmarkets.com/r/vd8akk-short?w=12
2. Proofpoint, Inc. US (2022) . https://www.proofpoint.com/sites/default/files/threat-reports/pfpt-us-tr-state-of-the-phish-2022.pdf
3. Proofpoint, Inc. US (2023). https://www.proofpoint.com/sites/default/files/threat-reports/pfpt-us-tr-state-of-the-phish-2023.pdf
4. Shafi'I, Muhammad Abdulhamid, et al. "A review on mobile SMS spam filtering techniques." IEEE Access vol. 5 (2017): pp. 15650-15666.
5. Mujtaba, Ghulam, and Majid Yasin. "SMS spam detection using simple message content features." J. Basic Appl. Sci. Res 4.4 (2014): pp. 275-279.
6. Gadde, Sridevi, A. Lakshmanarao, and S. Satyanarayana. "SMS spam detection using machine learning and deep learning techniques." 2021 7th International Conference on Advanced Computing and Communication Systems (ICACCS). Vol. 1. IEEE, 2021.
7. Sjarif, Nilam Nur Amir, et al. "SMS spam message detection using term frequency-inverse document frequency and random forest algorithm." Procedia Computer Science 161 (2019): pp. 509-515.
8. Alzahrani, Amani, and Danda B. Rawat. "Comparative

study of machine learning algorithms for SMS spam detection." 2019 SoutheastCon. IEEE, 2019.

9. Gupta, Suparna Das, Soumyabrata Saha, and Suman Kumar Das. "SMS spam detection using machine learning." Journal of Physics: Conference Series. Vol. 1797. No. 1. IOP Publishing, 2021.

10. Xu, Qian, et al. "Sms spam detection using noncontent features." IEEE Intelligent Systems 27.6 (2012): pp. 44-51.

11. Sethi, Gaurav, and Vijender Bhootna. "SMS spam filtering application using Android." Int. J. Comput. Sci. Inf. Technol 5.3 (2014): 4624-4626.

12. Nagwani, Naresh Kumar. "A Bi-Level Text Classification Approach for SMS Spam Filtering and Identifying Priority Messages." International Arab Journal of Information Technology (IAJIT) 14.4 (2017).

13. Shirani-Mehr, Houshmand. "SMS spam detection using machine learning approach." http://cs229.stanford.edu/proj2013/ShiraniMehr-MSSpamDetectionUsingMachineLearningApproach.pdf (2013).

14. Almeida, Tiago A., José María G. Hidalgo, and Akebo Yamakami. "Contributions to the study of SMS spam filtering: new collection and results." Proceedings of the 11th ACM symposium on Document engineering. 2011.

15. Kaggle SMS Spam Collection Dataset. https://www.kaggle.com/datasets/uciml/sms-spam-collection-dataset/data

IoT based Multipurpose Agricultural Robot

Gitesh B. Tulaskar
✉ gitesh06tulaskar@gmail.com

Vaishnavi V. Salunke
✉ vaishsal09@gmail.com

Raj R. Shetye
✉ shetyeraj912@gmail.com

Disha R. Mane
✉ dishamane2001@gmail.com

Priti Ravindra Sathe
✉ priti.sathe@vpmmpcoe.org

Department of Electrical Engineering
VPM's Maharshi Parshuram College of Engineering
Velneshwar, Maharashtra

ABSTRACT

This project proposes the development of an IoT-based agricultural robot equipped with multi-functional capabilities including seed sowing and grass cutting. The integration of IoT technology enables remote monitoring and control of the robot's operations, enhancing efficiency and reducing labor requirements in agriculture. The robot is designed to navigate autonomously within the field, utilizing sensors for obstacle detection and GPS for precise positioning. Additionally, it incorporates machine learning algorithms to optimize its tasks based on environmental conditions and crop requirements. Through this innovative approach, the proposed agricultural robot aims to revolutionize farming practices by increasing productivity, reducing costs, and promoting sustainable agriculture.

***KEYWORDS** : Agricultural robot, Seed sowing, Grass cutting, IoT.*

INTRODUCTION

In today's rapidly evolving agricultural landscape, the integration of technology has become imperative to address challenges such as labor shortages, resource optimization, and increasing productivity demands. One promising solution is the development of IoT-based agricultural robots, designed to revolutionize farming practices through automation and smart functionalities.

This project aims to design and implement an innovative IoT-based agricultural robot equipped with multifunctional capabilities including seed sowing, grass cutting. By leveraging Internet of Things (IoT) technology, the robot will be capable of autonomous operation, real-time data monitoring, and remote control, enabling farmers to efficiently manage their crops with minimal manual intervention.

The integration of seed sowing functionality allows for precise and uniform distribution of seeds, optimizing crop growth and yield. Additionally, the pesticide spraying feature enables targeted application, reducing chemical usage and minimizing environmental impact. The inclusion of a sprinkler system ensures efficient irrigation management, while the grass cutting function helps in maintaining field hygiene and weed control.

Through this project, we aim to address key challenges faced by modern agriculture, including labor shortages, operational inefficiencies, and environmental sustainability. By providing farmers with an advanced tool for crop management, this IoT-based agricultural robot has the potential to enhance productivity, reduce operational costs, and promote sustainable farming practices in a rapidly changing agricultural landscape.

Literature Review

The paper discusses the use of camera and machine vision-based systems in agriculture for seeding, weeding, and fertilizer spraying, which often incur high costs. It proposes a cost-effective and lightweight alternative that does not rely on expensive navigation equipment, making it advantageous for farmers. The system utilizes switches for crop selection, IR sensors for seed tank conditions and field detection, and DC motors for controlling the movement of mechanical parts for seeding operations. Power is supplied to the ARM7 board by a 9V battery and to the motors by a 12V battery source [1].

The Agribot utilizes an ATmega2560 microcontroller programmed with Arduino to automate irrigation along the contour of a rectangular field. Soil moisture and temperature sensors collect data, processed by Arduino, and used to irrigate soil uniformly. Data is transmitted to ThingSpeak cloud via a P8266 module for analysis. The system focuses on filtering, prediction, and compressing raw data. It consists of sensing, control, and output sections, with YL-69 and LM35 sensors for soil moisture and temperature, respectively. Hardware includes H bridges for motor control, relays for pump operation, and solar panels with a boost converter for energy supply, regulated by LM7805.[2]

The paper introduces a smart agriculture concept utilizing IoT sensors for field monitoring. An agribot, controlled by an ARM processor, automates seed sowing and monitors environmental factors. Solar technology powers the system. AI sensors and IoT enable crop monitoring, with cloud-based analysis and SMS alerts for farmers.[3]

This paper highlights the significance of agriculture in Bangladesh and the challenges it faces due to climate change and population growth. It proposes an IoT-based Smart Agriculture Robotic System to address these challenges. The system monitors various factors, activates devices accordingly,666 stores data in the cloud for analysis, and allows remote control via a mobile app, aiming to enhance agricultural productivity [4]

The AT89S52 microcontroller controls ploughing, seeding, levelling, and water spraying through motor drivers. L293D drivers control DC motors for each operation. The system, developed in hardware and software phases, interfaces with a Bluetooth module and is tested with a Bluetooth app. The prototype covers 11.4m distance, moves at 5.2m/min, and lifts 150gm per 1cm[5]

The Agribot is an autonomous agricultural robot aimed at reducing farmer labour while improving work speed and The proposed system involves wheeled mobile robots, Master and Slave nodes, equipped with sensors for autonomous field navigation. The Master robot utilizes Raspberry Pi for weed detection via image processing and forms a sensor network using NRF Protocol. Slave robots join the network, sending data to the Master node. Image segmentation and edge detection distinguish weeds from crops. Feature extraction via Local Quinary Patterns (LQP) and Histogram of Oriented Gradients (HOG), followed by Artificial Neural Network (ANN) classification, enables precise weed detection. ANN comprises two hidden layers with 40 neurons each, utilizing 160 extracted features for classification, accuracy. It conducts essential farming tasks such as ploughing, seeding, and soil covering. Controlled by a PSoC (Programmable System on Chip) controller from Cypress Semiconductor, USA, it offers optional switching for the ploughing system as needed. [6]

The project focuses on designing a multipurpose agricultural robot capable of digging soil, levelling, and monitoring water levels. Controlled by a PIC microcontroller, it utilizes humidity and moisture sensors for environmental monitoring and employs Bluetooth for communication with farmers. The robot aims for hands-free operation and efficient agricultural tasks.[7]

Research in agricultural robotics has surged, focusing on tasks like weeding and harvesting due to labour shortages and rising costs. Challenges remain in speed and accuracy, with notable progress in fruit picking with technologies like SWEEPER. Multidisciplinary collaboration is vital, emphasizing sensor optimization and the development of simple manipulators and multi-robot systems for automation.[8]

Agricultural robots are advancing to meet traditional farming needs, aiding in tasks from soil testing to fruit picking. They excel in weeding and harvesting, surpassing human efficiency. Multi-use platforms are developed, leveraging GPS and AI for navigation. The emerging robotic sector in agriculture offers job opportunities and attracts younger generations, promising increased production.[9]

Agricultural robots, including the milk bot in farming, are increasingly utilized in developing countries due to their wide-ranging benefits in various sectors like horticulture and environmental management. RV 100 facilitates product transportation. As research and technology advance, robots are diversifying in agricultural operations, emphasizing the need for academic programs to incorporate robotics education for further development.[10]

The system utilizes sensors like moisture, gas, and humidity sensors, along with LED lights, to automate plant care in indoor farming. It activates pumps or sprinklers based on water and humidity levels, while the MQ135 sensor ensures air quality. An assistant robot facilitates remote monitoring, while a line follower robot enables real-time surveillance and tasks like fertilizer application. Autonomous operation and automatic robot recharging are key features, validated through prototypes and simulations.[11]

Advancements in farming integrate remote sensors, drones, and robotics, fuelled by IoT connectivity for farm automation. Research focuses on task segmentation for robotic efficiency and AI-driven decision-making. Material science innovations propose carbon nanotube-based drones for energy efficiency. Smart farming encompasses precision agriculture and climate control, relying on robotics, IoT, and AI for increased productivity.[12]

PROPOSED SYSTEM

The envisioned system is dedicated to crafting a versatile agricultural robot with an integrated irrigation mechanism, designed to execute various essential tasks including ploughing, seeding, and soil levelling. This multipurpose agricultural robot facilitates seamless control over these three functions: soil excavation, precise seed deposition, and ground levelling for optimal planting conditions, while incorporating a water spraying feature for irrigation purposes. Notably, the system aims to maintain cost-effectiveness by minimizing accessory changes, achieved through seamless Bluetooth connectivity. The proposed model's block diagram, depicted in Figure 1, illustrates the interconnected components orchestrating these functionalities to enhance agricultural efficiency and productivity.

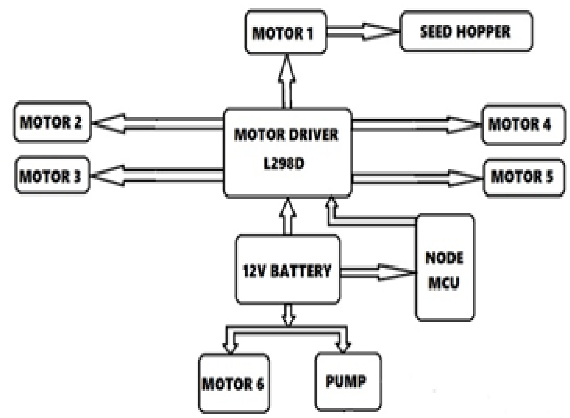


Fig 1 : Block diagram of IOT based multipurpose agricultural robot

When structuring the design, we meticulously consider both the environmental conditions and the functional requirements. The rotor body, serving as the seed dispersal outlet, forms the second crucial element. Utilizing CAD programming, the base component, robot body, digger and mid van are meticulously crafted. The base component features an aperture atop, facilitating seed loading, which seamlessly integrates with the framework. The rotor body incorporates an extendable cylinder, enabling precise seed release onto the designated area, as illustrated in Figure 2.

(a)

(b)

Fig. 2. (a) Front view and (b) Top view of construction of multipurpose agricultural robot

METHODOLOGY

Designing an agriculture robot with seed sowing, water spraying, and grass cutting functionalities, all integrated with IoT, involves a multi-faceted methodology. Firstly, comprehensive research into existing agricultural practices, crop types, and soil conditions is crucial to inform the robot's design parameters. This involves understanding the specific requirements for seed sowing depth, water dispersion rates, and grass cutting heights. Next, the hardware components, such as robotic arms for seed sowing and grass cutting mechanisms, need to be selected or custom-designed to meet the requirements. These components would be integrated with IoT sensors for real-time monitoring of soil moisture levels, weather conditions, and crop growth stages. Additionally, the robot's control system would be programmed to adjust seeding, spraying, and cutting actions based on data received from the IoT sensors. Field testing and iterative refinement would be essential to validate the robot's performance and optimize its efficiency in various agricultural settings. Finally, user-friendly interfaces for farmers to interact with the robot, either through a mobile app or web dashboard, would enhance usability and ensure seamless integration into existing farming practices.

The robotic system relies entirely on a 12V battery to function. It features a base frame equipped with four wheels connected to four arms powered by a DC motor. One end of the frame hosts a cultivator driven by another DC motor for soil excavation. Seed distribution is achieved through a drilled shaft linked to the soil processing mechanism. A leveller closes the seeds, while a water pump sprayer irrigates the field. Control of the entire operation, including ploughing, seeding, and irrigation, is facilitated via Bluetooth technology from a smartphone. At the core of this system lies a NODEMCU ESP8266, which interfaces with Bluetooth modules, DC motors and motor driver L298D to execute various tasks such as ploughing, seeding, levelling, and water spraying. Commands sent from the smartphone via Bluetooth direct the robot's movements in four directions: forward, backward, right, and left. The NODEMCU ESP8266 interprets these commands to perform specific functions in the field.

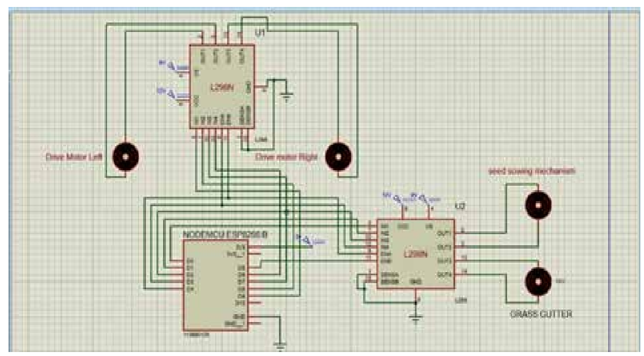


Fig. 3. Simulation of agricultural robot

From Fig 3. Shows the simulation results of the agricultural robot. The entire circuit is controlled by NODEMCU ESP8266. 12V dc supply is provided to the circuit. Motor driver L298D is used to control the motor rotations to left and right. The robot is controlled through Wi-Fi of android connected to the NODEMCU ESP8266. When the robot operates the and signals are given the digger operates following the spraying of water and then the seed gets placed through seed hopper. Similarly, the grass cutting operation also takes place.

CONCLUSION

The conclusion of an IoT-based multipurpose agricultural robot with seed sowing, water spraying, and grass cutting capabilities would highlight its potential to revolutionize farming practices. By integrating IoT technology, the robot can offer real-time monitoring and control, optimizing resource usage and improving efficiency. Additionally, its multifunctionality streamlines agricu3ltural tasks, reducing labour requirements and enhancing productivity. Overall, such a robot holds promise for increasing agricultural yield, promoting sustainability, and addressing the challenges faced by modern farming practices. Continued research and development in this field could lead to further advancements and widespread adoption of IoT-enabled agricultural robotics.

REFERENCES

1. G.SyedZabiyullah1,R.Gunasekaran2,A.Keerthana3,P. Kirubaharan4,S.Krishnamoorthy5,K.Rajeswari6, Agriculture robot for seeding and farming, ISAR - International Journal of Electronics and Communication Ethics - Volume 1 Issue 2, Mar – Apr 2018
2. E. Prasanthi1, M. Poojitha2, N. Sravani2, N. Sravani2, M. Vasundara2, IoT-based Solar Powered Agribot using Arduino Controller, Turkish Journal of Computer and Mathematics Education Vol.14 No.02 (2023),413- 421
3. Ms. B. Ragavi, Ms. L. Pavithra, Mrs .P. Sandhiyadevi, Ms. G. K. Mohanapriya, Ms. S. Harikirubha, Smart Agriculture with AI Sensor by Using Agrobot, 2020 Fourth International Conference on Computing Methodologies and Communication (ICCMC) 978-1-7281-4889-2/20/$31.00 ©2020 IEEE 10.1109/ ICCMC48092.2020.ICCMC-00078
4. Mehedi Hasan, Kamrul Nazir Walli Uddin, Ahosan Sayeed and Tasnuva Tasneem, Smart Agriculture Robotic System Based on Internet of Things to Boost Crop Production, 2021 2nd International Conference on Robotics, Electrical and Signal Processing Techniques (ICREST)
5. K Durga Sowjanya1, R Sindhu1, M Parijatham1, K Srikanth1, P Bhargav, Multipurpose Autonomous Agricultural Robot, International Conference on Electronics, Communication and Aerospace Technology ICECA 2017
6. Akhila Gollakota, M.B. Srinivas, AGRIBOT - A 66MULTIPURPOSE AGRICULTURAL ROBOT, Birla Institute of Technology and Science, Hyderabad Campus, Hyderabad 500 078
7. B S Balaji, Shivakumara M C, Sunil Y S, Yamuna A S, Shruthi M Smart Phone Operated Multipurpose Agricultural Robot International Journal of Engineering Research & Technology (IJERT) Vol. 7 Issue 05, May-2018
8. Redmond Ramin Shamshiri, Cornelia Weltzien2, Ibrahim A. Hameed3, Ian J. Yule4, Tony E. Grift5, Siva K. Balasundram1, Lenka Pitonakova6, Desa Ahmad7, Girish Chowdhary, Research and development in agricultural robotics: A perspective of digital farming, July, 2018 Int J Agric & Biol Eng Open Access at https://www.ijabe.org Vol. 11 No.4
9. Pramod Kumar Sahoo, Dilip Kumar Kushwaha, Nrusingh Charan Pradhan, Yash Makwana, Mohit Kumar, Mahendra Jatoliya , Mude Arjun Naik, Indra Mani Research and development in agricultural robotics: A perspective of digital farming 55 Annual Convention of Indian Society of Agricultural Engineers and International Symposium
10. P. K. Paul1, R. R. Sinha2, P. S. Aithal3, Ricardo Saavedra4, Bashiru Aremu5, and S. Mewada, Agricultural Robots: The Applications of Robotics in Smart Agriculture: towards More Advanced Agro Informatics Practice, Asian Review of Mechanical Engineering ISSN: 2249-6289 Vol.9 No.1, 2020, pp. 38-44© The Research Publication, ww.trp.org.in
11. A. Z. M. Tahmidul Kabir, Al Mamun Mizan, Nirmal Debnath, Akib Jawad Ta-sin, Nadim Zinnurayen, Md. Tanvir Haider, IoT Based Low Cost Smart Indoor Farming Management System Using an Assistant Robot and Mobile App, 2020 Electrical Power, Electronics, Communications, Controls and Informatics Seminar (EECCIS)
12. Akshay Krishnan, Shashank Swarna, Balasubramanya H. S, Robotics, IoT, and AI in the Automation of Agricultural Industry: A Review 978-1-7281-6828-9/20/$31.00 ©2020 IEEE

Electricity Generation by Train using Piezo

Aniket Suresh Paste
Lecturer
Department of Huminities
VPM's Polytechnic
Thane, Maharashtra
✉ namesteyaniket@gmail.com

ABSTRACT

An Abstract is regarding on Electricity Generation Using Piezo Material, Since Our Growing Countries there is Excessive Demand for Power there is need for Power in Every Situation whether the Commercial Sector, Industrial Sector or it in Residential in Transportation Sector There is Huge Demand for Power and Electricity for Human. Due to Excessive Power Consumption the is Maximum Demand for Power hence we had found power Generation by Train only as Our Most of Metropolitan City have Local Train There is Excessive Demand for Power continuously for 24x7 Hours. So today in our Project We Going to show Train Being Generate an Electricity using Piezo Material and even we going to show how Automatic Braking System is implemented in Train Using Electromagnetic Braking with Sensors.

KEYWORDS *: Piezoelectric sensor, Rack and pinion mechanism, Toy train (demo model), Electromagnetism, Electromagnetic sensor, Battery & multimeter.*

INTRODUCTION

This Introduction Show there is Track with Toy Train there is Wooden Block is Present for Support for our Track and In Between Piezo Plate is Placed as the Track had Flat bottom Surface so we required wooden support for track and Piezo electric plate Generate an Electricity. The Main Goal in this project is Electricity Generation by Train using Piezo Material under using an Mechanism as were mechanism been rolled on due to compressive force such could generate an electricity from piezo as well as generator

LITERATURE REVIEW

The Paper Titled "Railway Obstacle Detection and Power Storage" has been Proposed by S.Komalachitra, Bhargavi.S, Devika.R, Kumuthavalli.S, M.S.Narayani. This Strategy proposed at level crossings have image processing techniques been applied for obstacle identification. In different respects, identified by ultrasonic sensors that are connected to an 8051 microcontroller. The sensor heads send out ultrasonic waves, and the microcontroller receives the waves back reflected from the item. The effectiveness of it varies with the distance at which the rays are reflected. It has the ability to regulate the train's motion with the use of ultrasonic signals. The train is also using solar, wind, and other energy sources to harvest electricity. They are totally reliant on the weather.

The Paper Titled "Energy Harvesting from Human Walking to Power Biomedical Devices Using Oscillating Generation" has been proposed byJose A. Montoya, Dulce M. Mariscal and Edwar Romero. This Strategy at It is possible to gather energy for use in biomedical applications by using the alternating and rhythmic motion of limbs during movement. For example, wristwatches have been powered by body motion for many years. While studies have examined the possibility of using commercial electric wristwatch generators to power pacemakers

PROPOSED METHODOLOGY

In our Project we had discuss Piezoelectric this is used for Power Generation in our concept we going to use Disc (Round type) Piezoelectric Material for following

Specification given below

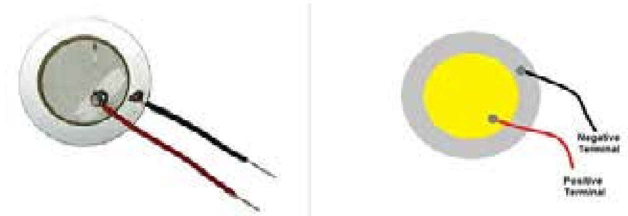


Fig. 1. Piezoelectric Sesnsor

Piezoelectric Sensor Pin Configuration

Pin Name	Description
Outer Circle	This Gives Negative Output Voltage.
Inner Circle	This gives Positive Output Voltage.

Piezoelectric Effect

The piezoelectric effect was discovered by Pierre Curie in 1880, but industrial sensing applications didn't begin to use it until 1950. The mechanical stress is converted into an electric charge by a piezoelectric sensor, which produces AC as the output.

A piezoelectric material's capacity to transform mechanical stress into electrical charge is known as its piezoelectric effect. The Greek word "piezein," which meaning to push, press, and squeeze, is where the word "piezoelectric" originates. Because the piezoelectric effect is reversible, an electrical charge is produced at the output when mechanical stress is applied to the piezoelectric material. Similar to how the sensor stretches or compresses when we apply an electrical charge to it.

Piezoelectric Material Available

Natural Piezoelectric Material	Synthetic Piezoelectric Material
Quartz	Lead Zinconate Titanate(PZT)
Rochelle Salt	Zinc Oxide(ZnO)
Topaz	Barium Titanate
TB-1	Piezoelectric Ceramics Barium Titanate
TBK-3	Calcium Barium Titanate
Sucrose	Gallium Orthophosphate (GaPO4)

Tendon	Potassium Niobate (KNbO3)
Silk	Lead Titanate

INTRODUCTION TO MECHANISM

In this Mechanism there is presence of two Rack have a height of 7.2cm.the Axle Length is 7.5cm. the larger Wheel had Diameter is 3.8cm and smaller Pinion Diameter is 1.8cm the similarly other side is also there with same Mechanism below its had one Spring which enclosed with that rack so the rack can act as the holder for that spring. When the rack comes along with reciprocating motion it create Piezo-electric effect. There is presence of one wooden Block Holder the size will been as shown in figure no.01the thickness of that block is about 1 mm.

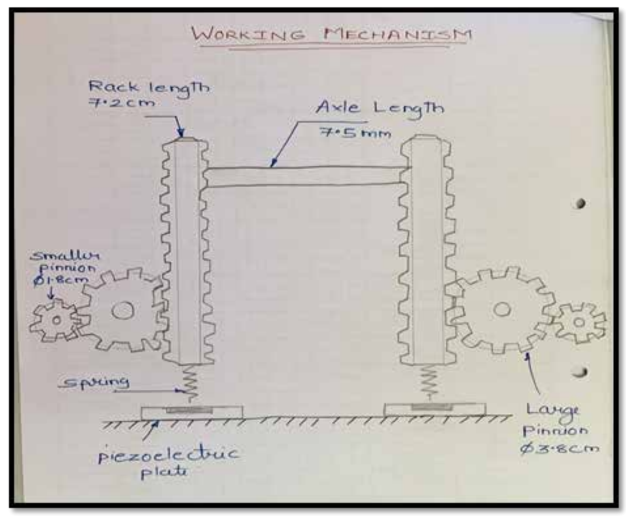


Fig 2. Working Mechanism

Working of Mechanism

1. In the Working there is presence of wooden Block about 1m distance apart there is piezoelectric plate

Is mounted with rack and pinion mechanism. The axle shaft is provided with support for our train

Track

2. When the train roles on the track as it passes in between the wooden support due to weight of train

Acting on the track the track gets deflect as were the mechanism which mounted in between the two Wooden support it gets into the motion.

3. The rack comes into the reciprocating motion and the larger pinion gets into the rotary motion as there

Is presence of intermediate contact between the rack and larger pinion. There is presence of

Intermediate contact between the larger pinion and smaller pinion so smaller pinion also rotates

4. Let's see the motion transmission system in this mechanism when rack comes under reciprocating

Motion in Fig 2.1 as when track deflects due to downward motion of rack due to intermediate contact

For rackwith larger pinion starts rotating in clockwise direction whereas smaller pinion rotates in

Anticlockwise Direction.

5. With the smaller pinion small A.C. Generator is mutually coupled with coupling and A.C. generator

Produces an A.C. Electricity which were stored at inside the battery.(Refer Fig 1.3)

6. When the Rack deflects into reciprocating motion as there is presence of smaller shaft at were spring

Is mounted in it's as that smaller shaft like structure provide apply downward force on piezoelectric

Plates as the plate produces an A.C. electricity. Thus, this electricity was stored into battery.

7. When there is not available sufficient light the sensor detects the photo rays and supply current from

Battery Towards to fan and tube light for railways station

8. During the night there is not sufficient light available in surrounding as photo sensor detects the light

Signal and turns on the light, fans, tube light and signaling units for train.

9. The same mechanism is also we going to use in railway station platform for electricity generation.

10. Due to excessive need of electricity in railways station platform for Day/Night due to presence of this

Mechanism our maximum amount of electricity is been stored inside the battery for required Consumption

Introduction to Automated Electromagnetic Braking System

In Electromagnetic Braking system there is presence of two sensors at start and end of train. When the train comes meets contact with sensor 1 it's activate electromagnetic system thus the sensor gets activated and train comes to tends in rest condition thus after certain period sensor 2 get deactivate the electromagnetic braking system. The train again comes under m

Working of Electromagnetic system

1. In Electromagnetic Braking System there are two sensors is mounted on the track where it detects train motion. When train comes indirect contact with sensor1 it activates electromagnetic braking system which also runs by battery.

2. Electromagnet brakes activate train braking system and comes under train with rest condition as

Where the sensor 2 (timer circuit) gets activated.

3. The certain periodical time interval sensor 2 deactivated and train again comes under motion Condition

RESULTS

Fig. 3 Result

In Above observation we founded that electricity is being produce piezo material were made from Rochelle Salt(Round disc type). So due to tapping on that disc its kindly produce 693mV

Current with a single plate as we going to connect in series form with two or more number of plate it will generate maximum output in form of voltage and current.

CONCLUSION

In this work we are concluded that due to parallel or series based circuit using of piezoelectric plate produces an energy which can been stored in batteries for further usage or any application purposes resultant to saving of cost of electricity consumption in day to day life. Also the generator were used in mechanism as shown in fig 2.1 also used for electricity generation.

In Automated Electromagnetic Braking system tends to avoid an accidental or instant braking for train were leads to avoid an accidents in Train.

REFERENCES

1. Y.C.SHU, I.C.LIEN, Analysis of power output for piezoelectric energy harvesting systems, Smart Materials and Strutures,15, 1499- 1512,2006
2. U.S. patent application Ser. No. 10/033,172, filed on Dec. 26, 2001, and entitled "HYBRID ENERGY POWER MANAGEMENT SYSTEM AND METHOD"
3. U.S. patent application Ser. No. 10/033,347, filed on Dec. 26, 2001, and entitled "HYBRID ENERGY LOCOMOTIVE ELECTRICAL POWER STORAGE SYSTEM"
4. U.S. patent application Ser. No. 10/032,714, filed on Dec. 26, 2001, and entitled "LOCOMOTIVE ENERGY TENDER".
5. G. Feltrin, "Wireless sensor networks: A monitoring tool for improving remaining lifetime estimation," in Civil Struct. Health Monitoring Workshop, Berlin, Germany, 2012, pp. 1–8.
7. Wikipedia: http://www.wikipedia.com
8. https://components101.com/sensors/piezoelectricsensor

Frank Polyphase Barker Sequences

T. D. Bhatt
Department of ECE
CMR College of Engineering & Technology
Medchal, Hyderabad
✉ dr.td_bhatt@cmrcet.ac.in

N. B. Soni
Department of Electrical Engineering
Maharshi Parshuram College of Engineering
Velneshwar, Maharashtra
✉ narendra.soni@vpmmpcoe.org

Gajanan Khapare
Department of Electronics & Computer Engineering
VPM's Maharshi Parshuram College of Engineering,
Velneshwar, Maharashtra

ABSTRACT

In 1953 Barker proposed biphase sequences that can be used in telecommunications for synchronization purposes. If all the correlation sidelobes are less or equal to one such sequences are called generalized Barker sequences and these sequences have wide applications in pulse compression radar systems. Sidelobes reduction technique is proposed in this paper that reduces peak sidelobes (PSL) of the Frank codes equal to one. Therefore, these sequences are referred as Frank polyphase Barker sequences. Additionally, both sides of the mainlobe, zero sidelobe regions appear which is useful for the detection and tracking of targets in dense target environment.

KEYWORDS *: Frank codes, Barker Codes, Autocorrelation, Pulse compression, Matched filter.*

INTRODUCTION

Correlation sidelobes along with the peak lobe (i.e. target position) at matched filter output is the main drawback of the pulse compression sequences. Such high sidelobes mask the weak target and prevent their detection in general. Major focus of the radar signal designers is to search the sequences which exhibit low correlation sidelobes. In 1953 Barker [1] proposed biphase sequences that can be used in telecommunications for synchronization purposes and have ideal sidelobe level that is equal to one, but such codes are available only up to length 13. Barkers codes of length 13 are not sufficient to achieve high range resolution due to its low compression ratio. The compression ratio of biphase codes or polyphase codes is equal to the sequence length. To achieve high resolution in range for separating closely spaced targets, large sequence length codes with good autocorrelation properties are required. Due to phase restrictions in biphase codes (i.e. either 00 or 1800) achieving very low sidelobes is a challenging task. Polyphase sequences are the another option to design the codes that can produce low sidelobes. In this context, Polyphase Barker sequences are the polyphase sequences with peak sidelobe level less than or equal to one are called generalized polyphase Barker sequences. There are no systematic approaches available in open literature for constructing polyphase Barker sequences. However, global optimization techniques are used to construct generalized Barker sequences. Examples of such sequences were found for all $N \leq 63$ [2–6]. Some other researchers also optimizes polyphase Barker sequences by using modified simulated annealing algorithm [7-8]. In open literature, many approaches are available for the reduction of sidelobes of polyphase codes [9-12]. There is no such approach which directly reduces the sidelobe level to a known a value that is less than or equal to one. This paper proposes the design procedure of polyphase sequences which which are derived from the Frank codes and has sidelobe level less than or equal to one. Therefore, these codes are referred as "Frank Polyphase Barker Codes". Section 2 gives the brief discussion about the polyphase Frank code. Section 3 explains the proposed method. Discussion of the results is given in section 4 and section 5 is the conclusions.

FRANK POLYPHASE CODE

The digital form of LFM or the codes obtained from quadratic phase shift representation or phase shift that is exhibited by digital form of LFM, generate the Frank codes for perfect square length. These codes can be designed only for the length $N = P^2$. Let the sequence of elements of Frank codes S_i ($1 \le i \le N$) can be given as:

$S_{(i-1)L+j} = \exp(j\phi_{i,j})$, where i and j varies from 1 to P. To obtain the value of $\phi_{i,j}$ that is the phase elements of the matrix is given as:

$$\phi_{i,j} = (2\pi/P)(i-1)(j-1) \tag{1}$$

The PxP matrix is generally used to represent the Frank codes. The phases of the P×P matrix are given by:

$$\begin{bmatrix} 0 & 0 & 0 & L & 0 \\ 0 & 1 & 2 & L & (P-1) \\ 0 & 2 & 4 & L & 2(P-1) \\ M & M & M & O & M \\ 0 & (P-1) & 2(P-1) & L & (P-1)^2 \end{bmatrix} \Delta\phi \tag{2}$$

With the help of the above matrix, one can design the Frank codes having four phases that is each element of the matrix is multiplied by ($2\pi/4 = \pi/2$) and this will give the phase angle of each subpulse. For example, by taking the value of P = 4, that will produce the phase matrix for length N = P2. The phase of each element will be derived by multiplying the P x P matrix by $\Delta\phi$, where $\Delta\phi = \pi/2$. The phase matrix is given in eq. (3)

$$\begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 1 & 2 & 3 \\ 0 & 2 & 4 & 6 \\ 0 & 3 & 6 & 9 \end{bmatrix} \Delta\phi \tag{3}$$

And in the j notation it is represented by equation (4)

$$\begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & j & -1 & -j \\ 1 & -1 & 1 & -1 \\ 1 & -j & -1 & j \end{bmatrix} \tag{4}$$

The final sequence of 16 element Frank code is:

$$S_{16} = \{1,1,1,1,1,j,-1,-j,1,-1,1,-1,1,-j,-1,j\} \tag{5}$$

Autocorrelation Function (ACF)

The radar receiver uses the matched filter to improve the peak signal to average noise ratio which is a correlator. In other words the output of the correlator is the auto-correlation between the replica of transmit signal and the reflected signal from the target. It is assumed that received signal is noise free. Let Si is the sequence transmitted by radar

$$S_i = [\, s_1, s_2, s_3 \ldots s_N] \tag{6}$$

The auto-correlation output is given by:

$$R(j) = \begin{cases} \sum_{n=0}^{N-j-1} s_i s_{i+j}^* \; ; & \text{wren } 0 \le j \le N-1 \\ \sum_{n=0}^{N+j-1} s_i s_{i-j}^* \; ; & \text{and when } -N+1 \le j \le 0 \end{cases} \tag{7}$$

The ultimate goal of the signal design is to control the sidelobe level and that can be measured by PSL. Mathematically PSL is calculated in dB by using the equation (8):

$$PSL = 20\,\log_{10}\left\{\left(\frac{\max_{i\neq 0}(R(i))}{r(0)}\right)\right\} \tag{8}$$

where R(i) represent the peak sidelobe of autocorrelation function.

In next section, proposed method for achieving PSL equal to one is explained.

PROPOSED METHOD

This paper presents a simple method that reduces the peak sidelobes at the output of a pulse compression filter equal to one. In proposed method, Frank sequence and one-bit shifted Frank sequences are multiplied by square root of 0.5 and then subtracted in a substractor block. The subractor block output is fed to the pulse compression filter that is matched filter, which is shown in Fig.1. The results obtained clearly shows that peak sidelobe level decreases to one.

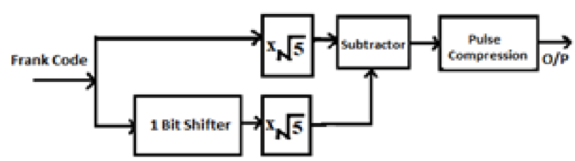


Fig. 1. Block Diagram of Proposed Method

SIMULATION RESULTS ANALYSIS

This paper is focused on peak sidelobe suppression of Frank codes. One bit shifted Frank code is subtracted from the original version of Frank code as shown in Fig.1. From the Figs. 2 and 4 it can be clearly observed that the peak sidelobe levels of proposed Frank codes for lengths N = 16 and 36 are 1, which is satisfying the condition of Barker codes. Additionally, Figures 3 and 5 are showing the sidelobe level in dB scale which verify that the suppression level is 20 log(1/N). Figs. 6 and 7 depict the ACF of original Frank sequence and polyphase Barker Frank sequence (Proposed Codes) respectively. From the comparison one can observe that the sidelobe suppression in case of proposed code is -60.21 whereas for original Frank code it is only -40.2 dB. Table-1 represents the PSL for various lengths of Proposed Frank polyphase Barker sequences varying from 16 to 2025. It can be clearly observed that the sidelobe suppression capability of the proposed technique is 20 log10(1/N), N being the length of Frank polyphase Barker sequence.

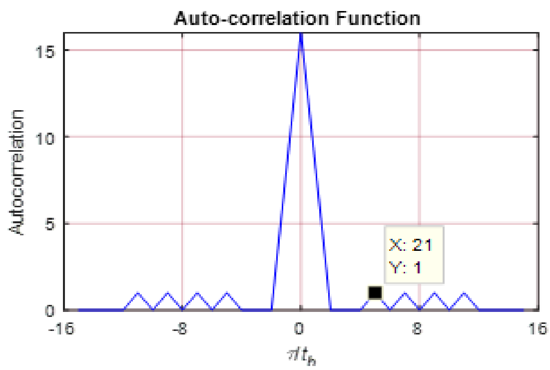


Fig. 2. ACF of Frank Barker code N= 16

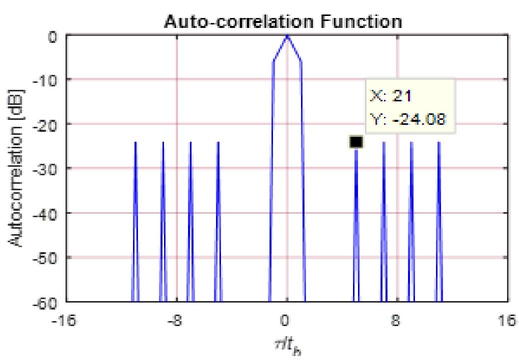


Fig. 3. ACF of Frank Barker code N = 16 in dB

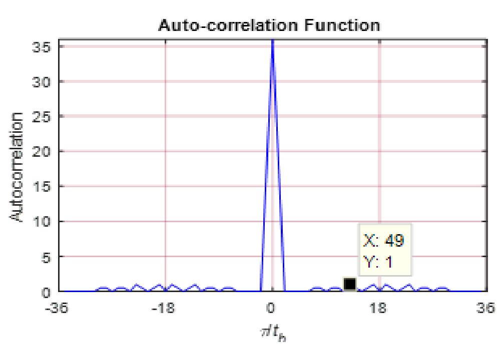


Fig. 4. ACF of Frank Barker code N= 36

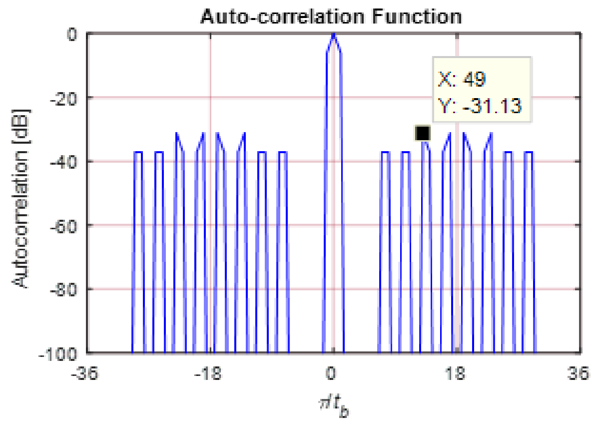


Fig. 5. ACF of Frank Barker code N= 36 in dB

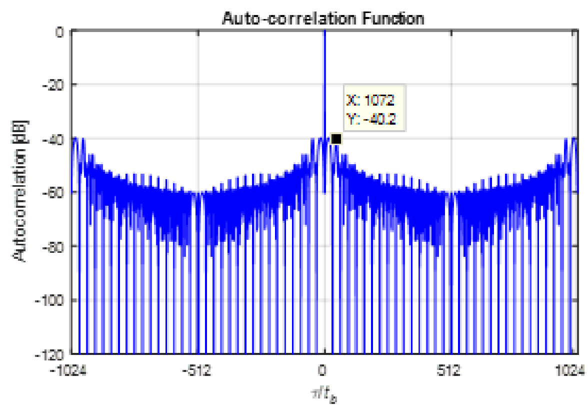


Fig. 6. ACF of Original Frank code N= 1024

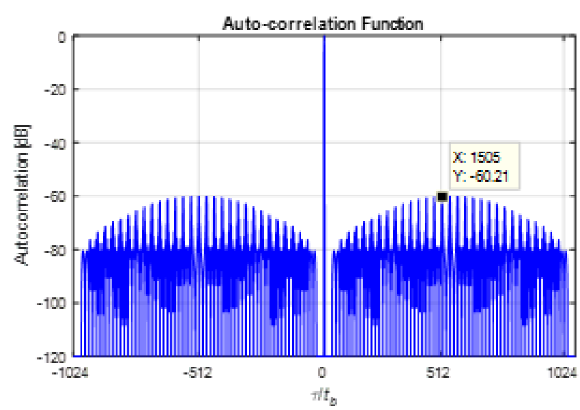


Fig. 7. ACF of Frank Barker code N= 1024

Table 1.

S. No.	Length of Code (N)	PSL of Proposed Frank Polyphase Codes (dB)
1	16	-24.08
2	25	-26.99

3	36	-31.13
4	49	-33.34
5	64	-36.12
6	81	-37.90
7	100	-40.00
8	144	-43.17
9	196	-45.85
10	324	-50.04
11	400	-52.04
12	484	-53.70
13	625	-55.88
14	900	-59.08
15	1024	-60.21
16	2025	-66.12

CONCLUSIONS

Frank codes are widely used polyphase codes for radar communication systems. Such pulse compression codes are used to achieve high range resolution and improve the signal to noise ratio (SNR) at the output of radar receiver. To detect small targets which are closely spaced with large target, the correlation sidelobes must be low. In Frank codes the sidelobes suppression is approximately -40.20 dB for the length N=1024 whereas by the proposed method it is suppressed to a level -60.21 dB which equal to 20 log (1/1024). This improvement in sidelobe supression is approximately 20 dB. It can also be notices from Figures 3 and 5 that the proposed Frank Barker codes exhibit a clear area near the mainlobe which is desirable in case of detecting and imaging the targets.

REFERENCES

1. R. H. Barker, "Group Synchronizing of Binary Digital Systems", Communication Theory, 1953 London: Butterworth. pp. 273–287.
2. L. Bomer, and M. Antweiler, "Polyphase Barker sequences", Electron. Lett. 25 (1989) 1577–1579.
3. M. Friese, and H. Zottmann, "Polyphase Barker sequences up to length 31", Electronics Letter, 30 (1994) 1930–1931.
4. M. Friese, "Polyphase Barker sequences up to length 36", IEEE Transaction Inf. Theory, 42 (1996) 1248–1250.
5. A. R. Brenner, "Polyphase Barker sequences up to length 45 with small alphabets", Electronics Letter, 34 (1998) 1576–1577.
6. P. Borwein, and R. Ferguson, "Polyphase sequences with low autocorrelation", IEEE Transactions Inf. Theory, 51 (2005) 1564–1567.
7. S. P. Singh, and K. S. Rao, "Modified simulated annealing algorithm for poly phase code design", Proceedings of 2006 IEEE International Symposium on Industrial Electronics, vols. 1–7, 2006, pp. 2966–2971.
8. S.P. Singh, and K. Subba Rao, "Thirty-two phase sequences design with good autocorrelation properties", Sadhana 35, 63–73 (2010). https://doi.org/10.1007/s12046-010-0001-5
9. R Lavanya, S.P Singh and T D Bhatt "Polyphase codes Sidelobes Suppression" IJECE Vol 2, Issue-4 ISSN: 2393-9028 (Print) | ISSN: 2348-2281 (Online) , Oct-Dec-2014,pp 47-50.
10. K. Vijay Ramya, A. K. Sahoo., and G. Panda, "Sidelobe Suppression Techniques for Polyphase Codes in Radar", International Journal of Computer Applications, 2011.
11. A. Thakur et al., "Side-lobe reduction in pulse compression having a better range resolution", Computers and Electrical Engineering, Vol. 74, March 2019, pp 520-532.
12. A. Thakur, and D. S. Saini, "Modifying polyphase codes to mitigate range side-lobes in pulse compression radar", Springer-Wireless Personal Communications, vol. 123, Mar 2022, pp. 693-707.

Non Coherent Pulse Compression Waveforms with Improved Energy Efficiency

T. D. Bhatt
Department of ECE
CMR College of Engineering & Technology
Medchal, Hyderabad
✉ dr.td_bhatt@cmrcet.ac.in

N. B. Soni
Department of Electrical Engineering
Maharshi Parshuram College of Engineering
Velneshwar, Maharashtra
✉ narendra.soni@vpmmpcoe.org

ABSTRACT

In case of conventional radars using the power oscillators such as magnetrons, coherence pulse compression cannot be achieved. Therefore, non-coherence pulse compression (NCPC) is used to detect and resolve closely spaced targets. This technique takes the advantages of square law detector in place of phase detector for detection of the received signal. This paper discusses about the periodic waveforms with higher energy efficiency which are most suitable for NCPC radar systems.

KEYWORDS *: Cross-correlation, Mismatch filter, Barker codes, m-sequences, non-coherent pulse compression.*

INTRODUCTION

In the design of radar signal, the concept presented by Woodward, plays significant role [1]. The basic idea is to obtain energy required for detection at the desired range is achieved by using a wide pulse and once detection requirements are met, resolution in range which is equal to short pulse can be obtained by increasing the bandwidth of transmitted pulse. To achieve high bandwidth, the transmitted pulse is to be modulated by using either phase or frequency coding. This new concept of signal design for radar applications is called pulse compression [2-5]. The first and widely used modulation technique is Linear Frequency Modulation (LFM). When the transmitted pulse is modulated, the range resolution becomes independent of pulse duration rather it is inversely proportional to the bandwidth B. This wide bandwidth is achieved by sweeping the frequency linearly for the duration of the pulse 'τ'. Wide bandwidth can also be obtained by changing the phases of the transmitted pulse. Some of the popular frequency coded waveforms used in radar are discrete frequency coding (DFC), Linear FM, Non-linear FM, stepped LFM etc. Whereas biphase codes and polyphase codes are the examples of phase coding techniques. Biphase codes are like Barker codes, m-sequences, minimum peak sidelobe sequences. Frank codes, P1, P2, P3, P4 codes are well known polyphase codes. Because of the simplicity in generation and implementation, biphase codes are preferred. To Achieve high resolution in range, received pulse must be compressed at the matched filter output and this can be achieved in two ways that is either by Coherent Pulse Compression (CPC), which is based on phase detection or using square law detector based on intensity of the received signal known as Non Coherent Pulse Compression. The advantage of biphase code is it can be used for both compression techniques. This paper proposes the NCPC codes which has higher energy efficiency and easy to implement in non-coherent systems.

PHASE CODED WAVEFORMS

In phase-coding technique the entire transmitted pulse having duration 'τ' is equally divided in N sub-pulses. This gives the duration of each sub-pulse equal to tB = τ/N. For achieving the desired bandwidth, each subpulse is coded in phase either either 00 or 180° keeping the frequency of the each sub-pulse constant. The order of the switching of each sub-pulse must be selected in such a way that the peak sidelobes (PSL) at the receiver output must be low. The radar of the receiver uses matched filter which gives the output as auto-correlation or cross-correlation of received and replica of the transmitted signals. The compression ratio (CR) of phase coded waveforms is equal to N that is number of sub-pulses N = τ/tB. The matched filter output is a narrow peak (mainlobe) of duration tB and magnitude is N. The remaining output peaks extended from –τ to +τ (τ ≠ 0) are known as "sidelobes", which are undesired and inevitable. To avoid the masking of small targets in the vicinity of large target, low sidelobes are desired. In other words, optimum waveform exhibits low PSL at the receiver output. When biphase codes are implemented in NCPC systems, the phase of the received signal is not important as it works on the principle of intensity of the received signal, which is shown in Fig.1. NCPC is explained in next section.

NON COHERENT PULSE COMPRESSION (NCPC)

The technique, which is referred as non-coherent pulse compression was suggested by N. Levanon [6-8]. This technique can be utilized where system is using the transmitting device such as magnetron or in laser communication where it is difficult to retain the phase and randomly the phases of sub-pulses are accepted. Some of the advantages of NCPC technique are discussed in [9]. The basic concept is where transmitter is either 'ON' or 'OFF' {i.e. 1 or 0} and also termed as on-off keying (OOK) signals. The radar systems using the devices like magnetrons, coherent pulse compression cam not be applied to these systems. However, NCPC technique can be successfully used. Block diagram that gives the concept of NCPC is shown in Fig. 1. The basic difference in NCPC compared to Coherent pulse compression is two valued reference signal, which is derived from the transmitted sequence {1,–β}.

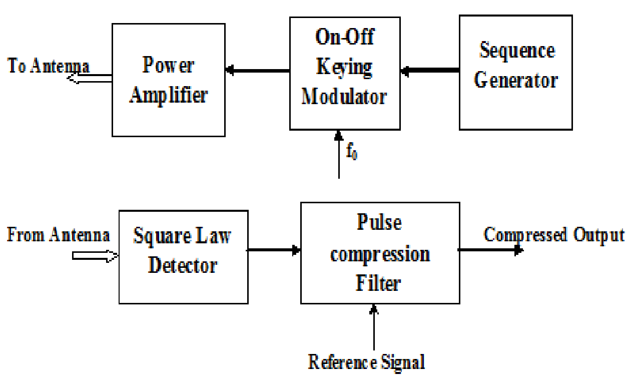


Fig. 1. Basic Blocks of NCPC system

First to understand the aperiodic signal efficiency, consider Barker Manchester codes let it represented by 'a'. Its reference signal which is denoted as 'b' is derived from the transmitted signal. In case of Manchester coding, calculation of reference signal is easy and can be derived simply by substituting '-1s' in place of '0s'. The mismatch filter's output which is depicted in Fig. 2 is referred as cross-correlation between 'a' & 'b'. To convert 13 bit Barker code in Manchester code, replace 1 with 10 and -1 with 01 which doubles the length of the code.

a = [1 1 1 1 1 -1 -1 1 1 -1 1 -1 1] = [10 10 10 10 10 01 01 10 10 01 10 01 10] (1)

and its reference signal is represented by replacing '0' with '-1' and given as:

b = [1-1 1-1 1-1 1-1 1-1 -11 -11 1-1 1-1 -11 1-1 -11 1-1]. (2)

$$\sum_{k=1}^{N} |a_k|^2 \, b_k \tag{3}$$

Equation (3) gives the cross-correlation between 'a' and 'b'. Cross-correlation of sequences (1) and (2) are shown in Fig.2.

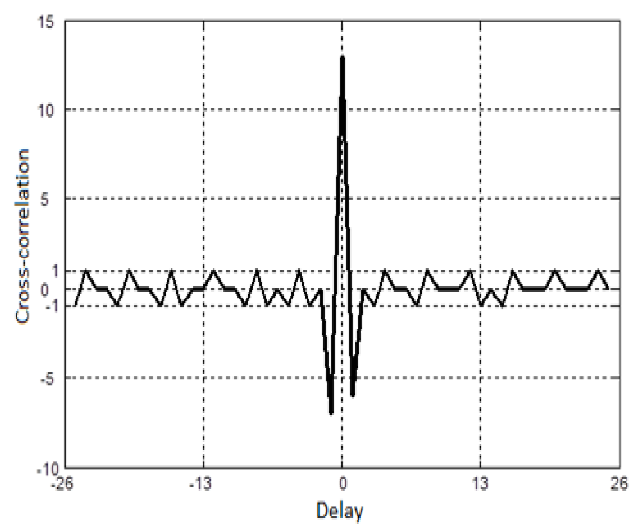


Fig.2. Cross-correlation function of Barker Manchester code N = 26

The sequences that exhibit lowest periodic autocorrelation are M-sequences, which is equal to $|rii(\tau \neq 0) = -1|$. Binary M-sequences, which are generally represented by ±1 and length of the sequence equal to N, gives constant sidelobes value equal to -1, and mainlobe magnitude is N in their periodic auto-correlation.

PERIODIC WAVE-FORMS

Periodic Biphase Codes

This section discusses about the periodic biphase codes that can be used for NCPC systems. The property of the m-sequences that can be exploited for coherent processor applications is that the periodic sidelobes are constant and equal to -1 and magnitude of peak lobe is N, which is given in Eq. (4):

$$r_{ii}(\tau) = \begin{cases} N & \text{when } \tau = 0,\ N,\ 2N, \cdots \\ -1 & \text{otherwise} \end{cases} \quad (4)$$

When these sequences are applied to NCPC systems, all -1's are replaced with zeros because NCPC system is either ON or OFF. Therefore due to more number of zeros in transmitted signal the efficiency approaches 50% when m-sequence length is very large. As shown in Fig.3, the peak value of the mainlobe is 4 whereas the sequence length N=7. This reduction in mainlobe is due to less number of 1's in transmission signal. As there are only 4 1,s in transmitted signal hence energy efficiency is 57.14%. Less number of 1's reduces the duty cycle of transmitted pulse and hence reduced energy efficiency.

The efficiency denoted by (η) of the signal can be given by:

$$\eta = \sum_{n=0}^{N-1} \frac{s^2(n)}{|s^2(n)|_{max}} \quad (5)$$

Improved duty cycle can be achieved by using the sequences which have less number of zeros & more number of 1's and such sequences must have the property of perfect periodic auto-correlation. The ternary m-sequences which demonstrate above mentioned properties are discussed in next section.

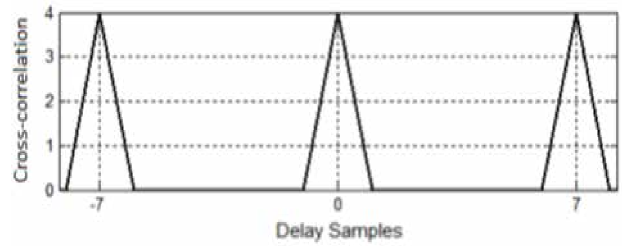


Fig. 3. Periodic Cross-correlation of m-sequence, N=7

Sig: [1 1 1 0 1 0 0]; Reference: [1 1 1 -1 1 -1-1]

Perfect Ternary m-Sequences

This section presents the design of multilevel m-sequences by using the anti-symmetric property [10], and based on the study it was found that these sequences hold good for coherent and non-coherent applications.

(i) Anti-symmetric property: For every 'p' prime, (p > 2) the even length m-sequence is always anti-symmetric, it means that the second half part of the of the even length sequence is same as the modulo(p)complement offirst half.This can be observed from the sequence shown for length N= 26 in table-1. In mathematical terms, the second half of a p-level m-sequence signal s(t) is given by:

$$s(t) = - s(t + (1/2)Nt_b) \quad (6)$$

where 'tb' is the clock-pulse period or bit duration, and N represent the m-sequence length. The improved energy efficiency of ternary sequences for lengths 13, 26 and 121are shown in Table-1. The value of β in reference signal can be calculated by using Eq. (7) for odd sequence length.

$$\beta = -\frac{((N-1)-M)}{M} \quad (7)$$

where N = Sequence length and N is odd positive integer; M = total number of 0's in sequence.

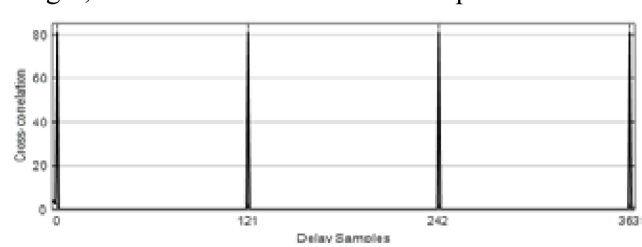


Fig. 4. Cross-correlation Function of Ternary m-sequence N=121 (Non-coherent processing)

Table-1: Perfect Periodic Ternary Sequences for Non-coherent Processing

Sequence length (N)	Energy efficiency (η in %)	Ternary m-sequences for Non-coherent Processing (Signal & Reference)
13	69	**Sig**: [1 0 1 0 0 1 1 1 0 1 1 1 1]
		Ref: [1 β 1 β β 1 1 1 β 1 1 1 1; (β= -2)]
26	69	**Sig**: [0 1 0 1 1 1 1 1 0 1 1 1 0 0 1 0 1 1 1 1 1 0 1 1 1 0]
		Ref: [β 1 β 1 1 1 1 1 β 1 1 1 β β 1 β 1 1 1 1 1 β 1 1 1 β; (β = -2)]
121	67	**Sig:** [0 0 1 1 1 0 1 1 0 1 1 0 1 1 0 1 1 1 1 1 0 0 0 0 1 0 0 0 1 1 0 0 1 1 1 0 1 0 0 1 1 1 0 1 1 1 1 1 0 1 0 1 1 1 1 1 0 1 1 0 1 1 1 1 1 1 0 0 1 0 1 0 1 1 1 1 1 1 1 1 1 0 1 1 1 1 1 1 1 0 0 0 1 1 0 0 1 0 1 0 1 1 1 1 1 1 0 1 0 0 1 1 1 0 1 0 1 1 1 1 1].
		Ref: [β β 1 1 1 β 1 1 β 1 1 β 1 1 β 1 1 1 1 1 β β β β 1 β β β 1 1 β β 1 1 1 β 1 β β 1 1 1 β 1 1 1 1 1 β 1 β 1 1 1 1 1 β 1 1 β 1 1 1 1 1 1 β β 1 β 1 β 1 1 1 1 1 1 1 1 1 β 1 1 1 1 1 1 1 β β β 1 1 β β 1 β 1 β 1 1 1 1 1 1 β 1 β β 1 1 1 β 1 β 1 1 1 1 1] ; (β= -2)

CONCLUSION

ON-OFF Keying modulation is preferred in radars or radar like system where coherent processing can not be implemented. the Non-coherent pulse compression uses square law detector in receiver and such systems work on intensity of the echo signal. Aperiodic on–off pulse sequence for NCPC processor using Manchester coded waveform of Barker code is presented. Two major drawbacks of the Manchester coding are (i) two negative peaks which are appearing close to the mainlobe (ii) energy efficiency which is equal to 50%. In case of binary m-sequences the energy efficiency approaches 50% as the length of the sequence increases. Perfect periodic ternary m-sequences are proposed for non-coherent pulse compression which has higher energy efficiency. Another advantage of proposed sequences is that these sequences can be used simultaneously for coherent as well as NCPC applications.

REFERENCES

1. P. M. Woodward, "Probability and Information Theory with Applications to Radar", Pergamon Press, Oxford, (1953).
2. A. Richards, Mark., "Fundamentals of Radar Signal Processing", Tata Mc Graw Hill, New Delhi, (2005).
3. Skolnik, Merrill I., "Radar Hand Book" McGraw-Hill, New York, (1990).
4. M. Bernfeld, and C.E. Cook, "Radar Signals: An Introduction to Theory and Application", Academic Press Inc., London, (1967).
5. Skolnik, Merrill I., "Radar Hand Book", McGraw Hill, New Delhi, (2008).
6. N. Levanon, "Noncoherent pulse compression", IEEE Trans. on Aerospace and Electronic Systems, vol. 42, pp. 756-765, (2006).
7. N. Levanon, "Noncoherent Radar Pulse Compression Based on Complementary Sequences", IEEE Trans. on AES Vol. 45, no. 2, pp. 742-747, (2009).
8. N. Levanon, I. Cohen, N. Arbel, and A. Zadok, "Non-coherent pulse compression – aperiodic, and periodic waveforms", IET Radar, Sonar & Navigation, vol. 10, issue 1, pp. 216-224, (2016).
9. E. V. Suryanarayana, P. Siddaiah &Tara Dutt Bhatt , Pulse Compression Waveforms: Applications to Radar Systems, Advances in Decision Sciences, Image Processing, Security and Computer Vision, pp 61–68 (2019).
10. K. R. Godfrey, "Three-level m sequences," in Electronics Letters, vol. 2, no. 7, pp. 241-243,(1966). https://doi.org/10.1049/el:19660204.

IoT based Surveillance Robot

Soheb Tadavi, Paresh Rane
Adesh Shigwan, Pranav Surve
Student
Department of Electrical Engineering
VPM MPCOE
Velneshwar, Ratnagiri, Maharashtra
✉ tadavisoheb25@gmail.com

Satish Ghorpade
Assistant Professor
Department of Electrical Engineering
VPM MPCOE
Velneshwar, Ratnagiri, Maharashtra
✉ satish.ghorpade@vpmmpcoe.org

ABSTRACT

The main goal of IOT based Surveillance Robot is to design and develop a surveillance robot that is capable of being used for rescue and spying in military operations. It is known that humans cannot venture into hazardous/disaster-affected places as it can be life threatening and hence robots are required where human intervention is nearly impossible. The proposed system employs a network of smart sensors and cameras mounted on a mobile robotic platform, enabling real-time data collection and analysis. The robot acts as a surveillance device to catch the trespasser surrounding information before the trespasser attacks the soldiers. Wireless surveillance robots can help to prevent the endangerment of humans or animals. The IOT based surveillance robot offers increased flexibility and efficiency in monitoring diverse environment, contributing to improved situational awareness. The paper discusses the design, implementation and experimental result of the system, highlighting its potential applications in such areas like public safety, industrial surveillance and emergency responses. The findings demonstrate the feasibility and effectiveness of leveraging IOT for enhanced surveillance capabilities through autonomous robotic platform. The robot can also be used by rescue teams to detect human beings quickly during natural disasters like earthquakes if any human beings are trapped under debris.

KEYWORDS *: IOT, Surveillance, Robot, Live stream, BLYNK App, ESP32 CAM module, Buck converter, Ultrasonic sensor, Gas sensor.*

INTRODUCTION

In recent years, advancements in automation and robotics have revolutionized surveillance capabilities, offering significant benefits in terms of reducing human errors and labor. Surveillance robots, integral to this transformation, are designed for monitoring and reconnaissance tasks, contributing to enhanced security in various domains such as border control, public spaces, offices, and industries. These robots, equipped with advanced sensors and communication systems, enable continuous monitoring of activities, facilitating prompt responses to abnormal occurrences. Utilizing Wi-Fi technology, IoT-based multipurpose surveillance robots have emerged as a promising solution, offering remote operation capabilities via smartphones and live video streaming for effective monitoring.

Research efforts have been directed towards developing surveillance robots tailored for diverse applications. For instance, projects like those outlined by Anandravisekar et al. (2019), Divakar et al. (2021), Kumar et al. (2022), and Sunitha et al. (2023) focus on designing robots for surveillance tasks in domestic environments, military operations, border security, and home security, respectively. These initiatives highlight the versatility of surveillance robots in addressing various security challenges, from domestic intrusions to hazardous disaster zones. By leveraging IoT technologies, these robots offer remote control capabilities, real-time data transmission, and live video feeds, empowering users with comprehensive surveillance functionalities. As robotics continues to advance, the integration of IoT and artificial intelligence promises further enhancements in surveillance capabilities, ensuring safer and more secure environments for individuals and organizations alike. [1 -3]

EXISTING SYSTEM

The existing system of an IOT based surveillance robot using ESP32 CAM module employs. It captures images or stream video footage and transmits it wirelessly over Wi-Fi. These sensors transmit data to the central processing unit which analyse the information and triggers action like recording video, sounding alarms, sending notifications to a remote operator via the internet. The robot is usually equipped with motorized wheels for movement, controlled remotely through a smartphone or computer interface. Motion detection algorithms are used to trigger recording or alert notifications. Remote control and monitoring are enabled through a web server hosted on the ESP32 CAM module. The system is powered by the rechargeable batteries for mobility. It may incorporate additional sensors for the real time monitoring and security surveillance in various environments. Recorded data can be stored locally on a SD card or uploaded to the cloud storage service. It offers for cost effective solution for the basic surveillance applications. It might have feature like night vision or obstacle avoidance to enhance its surveillance capabilities.

PROPOSED SYSTEM

The proposed system integrates an ESP32 CAM module for wireless surveillance. It can be utilize the ESP32's processing power for image capture and analysis. Motion detects triggers real time alerts and recording. Remote monitoring is enabled through a web interface accessible via Wi-Fi. The robot mobility is enhanced with motorized wheels controlled by the ESP32. Additional sensors like ultrasonic or gas can enhance environmental awareness. Cloud integration allows for remote storage and access to recorded footage. The system aims for easy setup and configuration through user friendly interface. AL algorithms for object recognition can enhance surveillance capabilities. It provides versatile and efficient IOT based solution for surveillance needs.

BLOCK DIAGRAM

This IOT based surveillance robot block diagram is as shown in the following fig.1

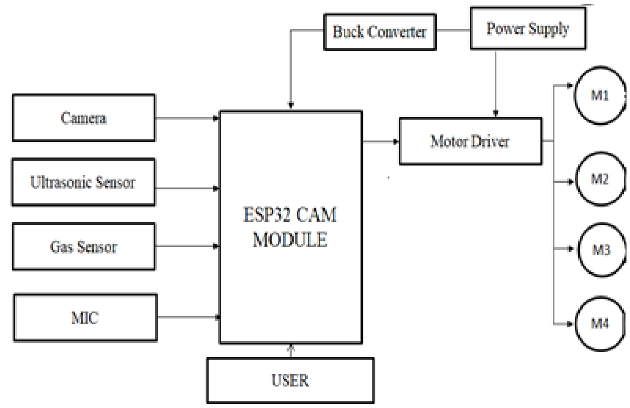


Fig.1 Block Diagram of IOT based surveillance robot

The main components of our block diagram are ESP32 CAM module, Motor Driver (L298N), Buck converter, Battery (7.4V), Gas Sensor, Ultrasonic Sensor, 4 DC Motors, and Camera as shown in fig-1. The ESP32-CAM module integrates Wi-Fi, Bluetooth and 2 MP Camera making it ideal for IOT surveillance robot enabling remote monitoring and analysis via Wi-Fi connectivity. Ultrasonic sensor enabling with ESP32 Cam module to detect nearby objects and obstacles, enhancing their navigation and monitoring abilities. Gas sensor detect various gases in the environment allowing IOT surveillance robot with ESP32 CAM module to monitor air quality and detect potential hazards. DC motors are used for controlling robot's direction. The BLYNK app is used to control and monitor motion of our robot. Buck converter regulate voltage essential in IOT surveillance robot with ESP32 CAM modules for efficient power management and ensuring stable operation.

VI. HARDWARE AND SOFTWARE REQUIREMENT

Hardware requirement are as follows:

ESP32 CAM Module

Fig. 2. ESP32 CAM Module

The ESP32-CAM module integrates an ESP32 SOC with a Wi-Fi, Bluetooth, 2 MP cameras, making it ideal for IOT surveillance robots. It enables to capture images and videos remotely. Its compact size and low power consumption make it ideal for embedded applications. It supports Wi-Fi connectivity for remote access and streaming, as well as a microSD card slot for local storage. The GPIO pins allow for interfacing with sensors and actuators, enabling custom robot functionalities. Its Arduino compatibility and active open-source community make development accessible for various surveillance applications. It's a versatile and cost effective solution for building IOT based surveillance robot.

MOTOR DRIVER (L298N)

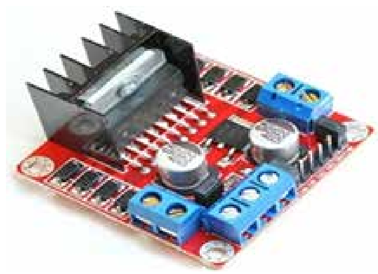


Fig. 3. Motor Driver L298N

The L298N motor driver is a dual H-bridge module commonly used in IOT surveillance robot to control DC motors for movement. The motor driver is used as an amplifier, to amplify the voltage supply to the motors. It provides bidirectional control, enabling forward, reverse and braking functions. With its high current capability and built in protection features, it ensures reliable motor operation. It can be easily interfaced with the ESP32, allowing precise control over robot movement. Its robust design makes it suitable for various robotics applications, enhancing the agility and responsiveness of surveillance robots.

DC SERVO MOTOR

Fig. 4. DC Servo Motor

Dc servo motor are employed for precise movement control, facilitating smooth navigation and enhanced agility. The rotor of servo motor is designed for longer in length and smaller in diameter so that there inertia is low. DC servo motor is used as 30 rpm. There are four DC motor are used. It is enable for the remote control operation and crucial for monitoring in diverse environment. Their utilization underscores a pivotal role in enhancing the performance and efficiency of surveillance robots, contributing to advancement in robotic surveillance technology.

ROBOT CHASIS AND WHEELS

Robot chassis is a simple accessory that particularly supports the making of a robot. Chassis is very essential component not only in construction but also for the mechanical devices. Chassis and wheels are pivotal for mobility and stability. The chassis should be light weight yet durable to withstand outdoor conditions. Design considerations emphasize material for lightweight yet durable construction, optimization the robot versatility. Wheel selection often priorities such as traction, size and compatibility with motor specifications. The component interfaced is handled by the chassis. This possesses simple construction with an acrylic plate and further holes are seen on the plate for connecting components and accessories on it.

BUCK CONVERTER

Fig. 5. Buck converter

Buck converter is essential component for efficient power management. They regulate voltage level ensure stable operation and prolonging battery life. It emphasizes their compact design and high efficiency, crucial for embedded applications with limited space and power constraints. Integration of buck converter enhances the overall energy efficiency and autonomy of surveillance robots, contributing to prolonged deployment and improvement performance. Their utilization underscores their significance in advancing the capabilities of IOT based surveillance robot.

GAS SENSOR

Fig. 6 Gas Sensor

Gas sensor plays a critical role in the environmental monitoring. These sensors detect various gases, aiding the identification of potential hazards and ensuring safety. Their sensitivity, accuracy and real time data acquisition capabilities, crucial for proactive surveillance in the surveillance robot. It integrates gas sensor enables autonomous detection and response to change in air quality, enhancing the robot situational awareness. Their utilization underscores their importance in enhancing the surveillance capabilities of IOT based system for diverse applications.

ULTRASONIC SENSOR

Fig. 7. Ultrasonic Sensor

Ultrasonic sensors are pivotal for obstacle detection and navigation. These sensors emit high-frequency sound waves and measure their reflection, enabling precise distance measurements. Researchers emphasize their accuracy, reliability, and real-time data acquisition capabilities, essential for dynamic environments. Integration of ultrasonic sensors facilitates autonomous navigation and obstacle avoidance, enhancing the robot's operational efficiency. Their utilization underscores their significance in advancing the capabilities of surveillance robots for effective monitoring and surveillance tasks.

Buzzer

Fig. 8. Buzzer

Buzzer serves as auditory feedback devices for alerting operators or deterring intruders. These compact components emit audible signals based on predefined conditions, enhancing situational awareness. Researchers highlight their simplicity, reliability, and low power consumption, making them suitable for embedded applications. Integration of buzzers enables real-time alerts and notifications, enhancing the robot's effectiveness in surveillance tasks. Their utilization underscores their role in augmenting the sensor capabilities of IOT based surveillance systems.

Software requirements area as follows:

Blynk App: Blynk is an IOS and android platform designed to remotely manage Arduino devices over the internet. It functions as a virtual dashboard, allowing users to construct graphical interfaces for their projects through effortless manipulation of widgets.

Arduino IDE: The Arduino IDE is freely available open-source software that simplifies coding and uploading processes for Arduino boards. This versatile software is compatible with a wide range of Arduino boards, allowing for seamless integration and programming flexibility.

RESULT

IOT-based surveillance robot using the ESP32-CAM module typically yields a versatile and effective system for real-time monitoring and surveillance tasks. The surveillance robot provides real-time video streaming and monitoring capabilities, allowing users to remotely observe and respond to events in the monitored environment. Integration of sensors such as gas sensors and ultrasonic sensors enables the robot to detect and respond to threats in its surroundings, enhancing security and safety. The wireless connectivity of the

ESP32-CAM module facilitates easy deployment of the surveillance robot in surrounding environments. Optimized algorithms ensure efficient performance with lowest possible power consumption and extending the life span of the battery. The system offers cost effective and adaptable option for surveillance requirements, leading to enhanced levels of security and safety.

Fig. 9. Equipped Robot

CONCLUSION

The design, implementation, and evaluation of an IOT based surveillance robot utilizing the ESP32-CAM module in the surveillance robot. It can be demonstrated the integration of ESP32-CAM module offers a versatile and efficient platform for real-time monitoring. The surveillance robot developed enhanced situational awareness and response capabilities, effectively detecting and responding to potential threats or anomalies in its environment. All the sensor such as ultrasonic and gas sensors has increased the robot's functionality, enabling it to perform tasks such as obstacle detection and environmental monitoring with increased accuracy and reliability. Future effort should focus on refining power efficiency, incorporating complex algorithm and tackling stability issue to advance the capabilities of similar system. IOT-based surveillance robot systems and the potential of ESP32-CAM module based platforms for improving security and situational awareness in various environments. By persistently innovating and encouraging collaborative effort, these systems have the potential transform the methods by which we conduct surveillance and monitoring in the digital area.

REFERENCE

1. Chinmay Kulkarni, Suhas Grama, Pramod Gubbi Suresh, Chaitanya Krishna, Joseph Antony. "Surveillance Robot Using Arduino Microcontroller, Android Apis and Internet".Department of Electronics and Communication Engineering, National Institute of Technology, Karnataka, Surathkal, Mangalore, India. (2014)

2. Shaik Shoeb Maroof Nasima, Ansari Asgar Ali Shamshul Haque Shakina. "Surveillance Robot Controlled Using An Android Application". Department of Computer Engineering, School Of Engineering and Technology, Anjumaan-I-Islam's Kalsekar Technical Campus, Mumbai, India. (2015)

3. Shah, Mohammad Shoeb, and P. B. Borole. "Surveillance and rescue robot using Android smartphone and the Internet." 2016 International Conference on Communication and Signal Processing (ICCSP).

4. Mrs. M. Sunitha, P. V. S. S. Datta Vinay, V. S. N. Lokesh, B. Dinesh Kumar " Robot can be operated via mobile using Internet Of Things proceedings of the Fourth International Conference on I-SMAC (IOT in Social, Mobile, Analytics and Cloud) (I-SMAC) IEEE Xplore Part Number:CFP20OSV-ART, India.

5. J. Gao, X. Gao, W. Zhu, J. Zhu and B. Wei, “Design and research of a new structure rescue snake robot with all body drive system,” 2008 IEEE International Conference on Mechatronics and Automation, 2008.

6. Sushant Kumar and Dr. S. S. Solanki, “Remote Home Surveillance System “, 2016 International Conference on Advances in Computing, Communication, & Automation, 2016.

7. Pravallika GL, Rakesh P, Srikanth N, Hariguru YP. Multi-Application Surveillance Robot using IOT. International Research Journal of Engineering and Technology. 2021.

8. T. Akilan, Satyam Chaudhary, Princi Kumari, Utkarsh Pandey “Surveillance is nothing but monitoring from a distance by means of gadgets made by electronics, such as even robots” 2020 2nd International Conference on Advances in Computing, Communication Control and Networking (ICACCCN), India

9. Aishwarya K Telkar, Prof.. Baswaraj Gadgay “Surveillance robot that can reduce the casualties in the war field” Proceedings of the Second International Conference on Inventive Research in Computing Applications (ICIRCA-2020) IEEE Xplore Part Number: CFP20N67-ART India

Performance Analysis of Distance Relays in the Presence of Static Synchronous Series Compensator (SSSC) for Enhanced Power System Protection

Priti Ravindra Sathe*
✉ priti.sathe@vpmmpcoe.org

Yogesh Katdare
✉ yogesh.katdare@vpmmpcoe.org

Minal Sathe
✉ minal.sathe@vpmmpcoe.org

Department of Electrical Engineering
VPM's Maharshi Parshuram College of Engineering
Velneswar, Maharashtra

ABSTRACT

As technology continues to advance, Flexible AC Transmission Systems (FACTS) have become integral for enhancing the power transmission capacity of transmission lines and optimizing the utilization of power system capabilities. However, the integration of FACTS devices, such as Static Synchronous Series Compensators (SSSCs), introduces substantial changes in the system dynamics, thereby impacting the protection mechanisms of power systems. Notably, the alteration in the net impedance of transmission lines due to FACTS devices can lead to overreaching or under reaching issues in distance protection schemes. This paper investigates the performance of distance relays in the presence of SSSCs under various fault conditions. A thorough investigation was carried out on a 400kV transmission line spanning 300km, designed and simulated using MATLAB/SIMULINK software. The findings highlight the substantial impact of SSSCs on the mho characteristic of distance relays. Through the analysis presented in this paper, insights are provided into the effects of SSSCs on the operation of distance relays, offering valuable guidance for enhancing the protection and stability of power systems in the presence of FACTS devices.

KEYWORDS *: Transmission line, MATLAB/SIMULINK, FACTS, Series compensation, SSSC, VSC, Distance relay.*

INTRODUCTION

Solar power systems rely on managing active and reactive power flow and maintaining bus voltage levels. To overcome challenges like transient and voltage instability, methods such as adding series reactance or using Flexible AC Transmission System (FACTS) controllers are employed. FACTS controllers, like Static Synchronous Series Compensator (SSSC), enhance stability, regulate voltage, and manage power flow effectively [1, 3]. However, integrating compensation devices for reactive power can affect voltage and current values, impacting protection device operation and system reliability [4, 5].

Fault protection is crucial for uninterrupted power supply, but compensated lines pose challenges for traditional distance relays. This necessitates innovative fault location techniques [2, 7]. MATLAB/Simulink analysis explores the impact of SSSC on relay functionality, showing its effect on impedance-based relay operations [6, 7].

SSSC operates as a voltage source converter (VSC) in series with the transmission line, providing wider control range and independence from line current compared to traditional TCSC systems [2, 5]. By adjusting its output voltage, the SSSC regulates line impedance, improving transmission system performance [5, 12]. The VSC within the SSSC maintains voltage in or out of phase with line current, allowing for capacitive or inductive compensation without extra components [10, 14]. Adjusting DC voltage or using pulse-width modulation techniques enables dynamic control of transmission line impedance, enhancing transient stability [5, 14].

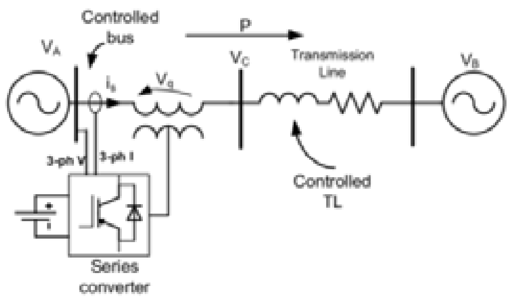


Fig.1 Basic Configuration of SSSC

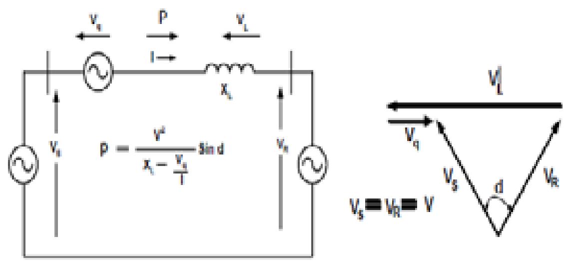
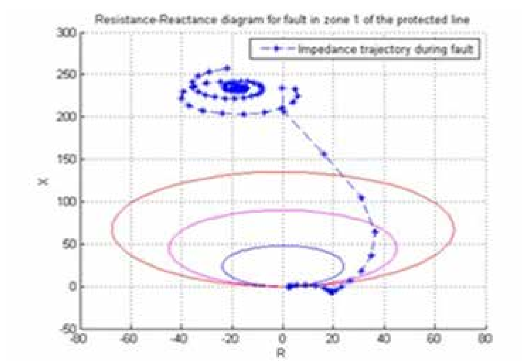
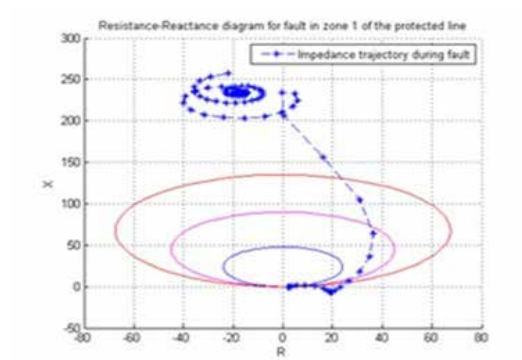


Fig.2 Elementary two-machine system with an SSSC

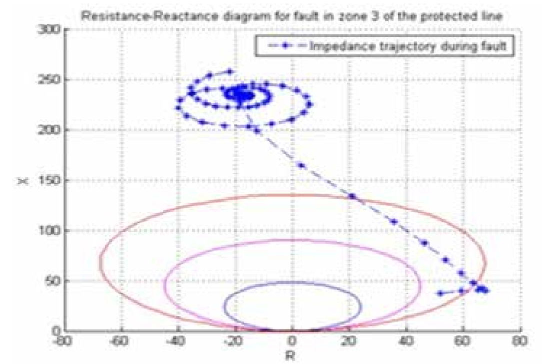
SIMULATION RESULTS WITH AND WITHOUT SSSC



Fault in zone 1 R-X diagram



Fault in zone 2 R-X diagram



Fault in zone 3 R-X diagram

Fig 3..Mho Charactreistics of Distance Relay without SSSC

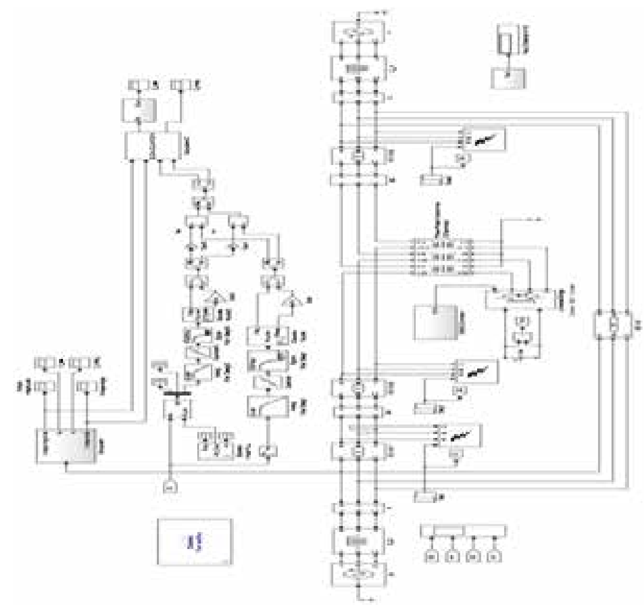


Fig 4 With SSSC simulation diagram

HARDWARE SETUP AND EXPERIMENTAL DETAILS

A hardware prototype of a transmission line with a distance relaying scheme was meticulously designed and constructed, incorporating a Static Synchronous Series Compensator (SSSC) to validate simulation results. The transmission line was modelled as a 230V double circuit doubly fed single-phase equivalent circuit spanning 300km, with each 100km section represented by pairs of inductance and resistance. Capacitance effects were disregarded due to the line's moderate loading and the focus on fault conditions during experimentation.

In the experimental setup, 100W lamps served as regular loads, while 200W lamps were used to simulate line-to-ground faults at different positions along the line. Voltage and current sensors were employed for accurate measurement of line parameters. A Voltage Source Converter (VSC) was connected in series via circuit breakers and a step-down coupling transformer. The algorithm for the distance relay and SSSC operation was implemented using the Arduino Uno platform, providing user-friendly control.

The distance relay reliably detected fault locations during normal operation, accurately identifying fault zones. However, in the presence of the SSSC, it exhibited limitations. While it effectively pinpointed faults in zone 1, it couldn't differentiate between faults in zone 1 and zone 2, erroneously displaying faults in zone 1 for both cases. Consequently, it failed to reach faults in zone 2, indicating an under-reaching issue. Additionally, it couldn't detect faults in zone 3 due to measured impedance falling below the relay's threshold, leading to a phenomenon of overreaching.

Despite these observed limitations, the hardware prototype provided valuable insights into the practical implementation of distance relaying schemes and the integration of SSSC technology into transmission line systems. Further refinements and adjustments may be necessary to address the identified issues and enhance the relay's performance in accurately detecting and classifying faults.

Fig. 5. Hardware Model

CONCLUSION

The project extensively investigates the behavior of a distance protection scheme for transmission lines under the influence of a Static Synchronous Series Compensator (SSSC) during single line-to-ground faults. It was observed that the distance relaying system experiences malfunction due to unpredictable impedance changes induced by the SSSC, ultimately leading to the failure of the distance protection system. Both simulated and experimental results corroborate these findings. The research explores the impact of faults at different points along the transmission line. Findings reveal that when an SSSC is placed between zone 2 and zone 3 of the transmission line, the effectiveness of distance relaying in these zones is compromised. However, zone 1 functions as anticipated. The analysis shows that the distance relay under-reaches in zone 2 when faults occur before the SSSC connection, whereas it over-reaches in zone 3. Addressing the issue of distance relay malfunction in the presence of the SSSC is crucial for ensuring the stable and reliable operation of power systems. Various algorithms can be developed to compensate for errors in distance relay measurements. Future research can explore the utilization of recent advancements in Artificial Intelligence, Fuzzy Logic, and Artificial Neural Networks to devise effective solutions to this problem, thereby enhancing the performance and reliability of distance protection schemes in transmission lines.

REFERENCES

1. N. G. Hingorani and L. Gyugyi, "Understanding FACTS Concepts and Technology of Flexible AC Transmission Systems" IEEE Press, 2000.
2. M. Faridi, H. Maeiiat, M. Karimi, P. Farhadi and H. Moslesh, "Power System Stability Enhancement Using Static Synchronous Series Compensator (SSSC)", IEEE Transactions on Power System, pp. 387- 391, 2011.
3. Dipendra Rai, Sherif O. Faried, G. Ramakrishna and Abdel-AtyEdris, "An SSSC-Based Hybrid Series Compensation Scheme Capable of Damping Subsynchronous Resonance", JEEE transaction on power delivery, vol. 127, no.2, 2012.
4. H. Zenk and A. S. Akpinar, "PI, PID and fuzzy logic controlled SSSC connected to a power transmission line, voltage control performance comparison," 4th International Conference on Power Engineering, Energy and Electrical Drives, pp. 1493-1497, Istanbul, 2013.
5. A. K. Jadhav and V. A. Kulkarni, "Improvement in Power System Stability Using SSSC Based Damping Controller," 2018 International Conference on Smart

Electric Drives and Power System (ICSEDPS), pp. 162-166, Nagpur, 2018.

6. M. Y. Suliman and S. M. Bashi, ”Fast response SSSC based on instantaneous power theory,” 2013 International Conference on Electrical Communication, Computer, Power, and Control Engineering (ICEC-CPCE), pp. 174-178, Mosul, 2013.

7. M. Rohal and Ravi, ”Application of SSSC based power oscillation damping controller for transient stability enhancement of multimachine system for unsymmetrical faults,” 2014 6th IEEE Power India Interna- tional Conference (PIICON), pp. 1-6, Delhi, 2014.

8. C. Anitha and P. Arul, ”Enhancement of voltage stability in transmission system using SSSC,” 2014 International Conference on Circuits, Power and Computing Technologies [ICCPCT-2014], pp. 30-33, Nagercoil, 2014.

9. C. U. Shankar, R. Thottungal and S. Mythili, ”Voltage stability improvement and power oscillation damping using Static Synchronous Series Compensator (SSSC),” 2015 IEEE 9th International Conference on Intelligent Systems and Control (ISCO), pp. 1-6, Coimbatore, 2015.

10. S. Gandhar, J. Ohri and M. Singh, ”Application of SSSC for com- pensation assessment of interconnected Power System,” 2014 IEEE 6th India International Conference on Power Electronics (IICPE), pp. 1-5, Kurukshetra, 2014.

11. S. Arun Kumar, C. Easwarlal and M. Senthil Kumar, ”Multi machine power system stability enhancement using Static Synchronous Series Compensator (SSSC),” 2012 International Conference on Computing, Electronics and Electrical Technologies (ICCEET), pp. 212-217, Ku- maracoil, 2012.

12. G. Maheswaran and K. S. Naidu, ”Comparison of fuzzy and PI controller based SSSC for damping of sub synchronous resonance,” 2014 International Conference on Science Engineering and Management Research (ICSEMR), pp. 1-5, Chennai, 2014.

13. F. D. Galiana, K. Almeida, M. Toussaint, J. Griffin and D.Atanackovic, “Assessment and Control of the Impact of FACTS Devices on Power System Performance”, IEEE Trans. Power Systems, Vol11, No 4, Nov. 1996.

14. A. Kazemi, S. Jamali and H. Shateri, ” Effects of SSSC on Distance Relay Tripping Characteristic,” 2006 IEEE International Power and Energy Conference, pp. 624-629, Putra Jaya, 2006.

15. A. Shojaei and S. M. Madani, ”Analysis of measured impedance by distance relay in presence of SSSC,” 5th IET International Conference on Power Electronics, Machines and Drives (PEMD 2010), pp. 1-6, Brighton, UK, 2010.

16. Amir Ghorbani, Babak Mozafari and Ali Mohammad Ranjbar, “Digital distance protection of transmission lines in the presence of SSSC” Elsevier, Electrical Power and Energy Systems, Vol. 43, pp. 712-719, 2012.

17. S. Jamali, A. Kazemi and H. Shateri, ”Effect of SSSC on measured impedance of distance relay in double-circuit lines,” 2007 42nd In- ternational Universities Power Engineering Conference, pp. 895-899, Brighton, 2007.

18. Dhenuvakonda, KR, Singh, A, Thakre, MP, Karasani, RR, Naidoo, R., “Adaptive digital distance relay for SSSC-based double-circuit transmis- sion line using phasor measurement unit”, Int Trans Electr Energ Syst., 2019.

Automatic Height Based Box Sorting System by Using PLC

Kunal Bakade*
✉ kunalbakade1730@gmail.com
Rhishish Hatiskar
Atul Tambe
Gauri Joshi
Department of Electrical Engineering
VPM's MPCOE
Velneshwar, Maharashtra

ABSTRACT

A Programmable Logic Controller (PLC) is a key component in an automated height-based box sorting system. This system utilizes sensors to detect the height of incoming boxes on a conveyor belt. The PLC receives this data and processes it to determine the appropriate destination for each box based on predefined sorting criteria. Depending on the height, the PLC triggers actuators or motors to divert the boxes onto different conveyor belts or chutes leading to specific destinations. The PLC's programming allows for flexibility in sorting criteria, enabling customization based on the needs of the application. This automation reduces manual labor, increases sorting accuracy, and enhances overall efficiency in warehouse or manufacturing environments. Additionally, PLC-based systems offer real-time monitoring and control capabilities, allowing operators to adjust sorting parameters as needed. Overall, the integration of PLC technology into height-based box sorting systems streamlines operations, improves productivity, and minimizes errors, making it a valuable asset in modern logistics and manufacturing processes.

KEYWORDS *: Programmable logic controller (PLC), Box sorting, Conveyor belt, Sensor, Motor.*

INTRODUCTION

Some companies, like the food processing and toy industries, regularly sort items with the objective to increase the rate of production. Sorting improves the system's efficiency. This system is a low-cost automation system that classifies light-weight boxes based on variations in height. It will enhance similarity and flexibility and minimizing manpower. This would reduce the quantity of laborious work that must be performed by hand in addition to averting the hazards related to working in hazardous conditions such chemical industries. The Ultrasonic Sensor and DC motor modules are interfaced with the PLC of this system to detect height and sort the elements suitably. For interaction with the ultrasonic sensor and continuously monitor the height of the boxes, a PLC is employed. The automatic system with a combination of PLC that has an important effect on object sorting is presented in this work. This system's main role is to operate , a sorter arm, and a PLC to automate the process of sorting the boxes to the relevant destination.

LITERATURE REFERENCES:

- Nilima Bargal, Aditya Deshpande, Rucha Kulkarani, Rucha Moghe published paper entitled as "PLC Based Object Sorting Automation". This paper represents employs photo-electric sensors and DC geared motors controlled by a Programmable Logic Controller (PLC) to sort three different height objects. The system includes a conveyor belt, pre-feed conveyor, and major conveyor. The main conveyor, powered by a 3-phase AC induction motor controlled by a VFD involvement with the PLC, takes objects to a height measuring station. The height measuring station consists of three metal plates holding proximity sensors, with the second plate adjustable to accommodate different sensor heights. The system optimizes energy usage by starting the conveyor only when an object is present and slowing down the conveyor when needed for accurate sorting [1]

- A. Gohulakrishnan, P. Balamurugan, N.H Ariharan, T. Dhanushvighesh, N. S Anthanakrishna published paper name as "PLC Based Sorting Operating Using Conveyor System". This paper represents the sorting of objects between a medium-sized object and a large-sized object. This object is sensed by infrared sensors. A DC geared motor is used to drive the conveyor belt at low RPM, which carries different sized objects. [2]

- Amey Karode, Pranav Mahajan, published paper entitled as "Objects Sorting Machine Using Arduino-Uno". This paper represents objects sorting with the help of an arduino. In these, an Ultrasonic sensor is used for sensing purposes. Using a 12v DC motor for driving the conveyor belt. For 12v Dc Motor L293D, a motor driver is used. If the object has a height that is less than the decided height, the conveyor belt moves towards the left side, and the object has a height that is greater than the decided height, the conveyor belt moves to the right side.[3]

- K. Amirtha, V. Girija, S. Preethi, S. Pradeep, published paper entitled as " Automatic Sorting System By Using PLC". The paper represent successful automation industry, innovation, productivity enhancement, cost reduction, and user-friendliness are crucial. PLC systems are instrumental in achieving these goals, particularly in our project focused on developing an automatic sorting system for height, width, and material detection. This system utilizes proximity and diffused beam photoelectric sensors for sensing, interfaced with a PLC-controlled DC motor. The motor drives a conveyor belt, positioning products in front of sensors for detection. The system includes a start sensor, initiating conveyor movement only when a product is present, conserving energy by shutting off when idle. A measuring station, comprising a mounted casing housing sensors, estimates object dimensions and material type. Additionally, the system integrates security features such as Emergency Stop, Human Interrupt analyzer, and Defect Product Indicators. This comprehensive approach ensures efficient and accurate sorting while prioritizing safety and energy efficiency, contributing to a robust and effective automation solution.[4]

- P. Thirumuurugn, R. Aravind, M. Arun Kumar, S. Dharshan Manjunath, R. Kalaiselvan, Published paper entitled as" Automatic Sorting in process Indurtries Using PLC" The sorting process involves integrating the conveyor system with the PLC system, comprising conveyor belt, sensing section, and PLC section. Objects are transferred through the conveyor belt to the sensing area, where a sensor detects their height. This sensor-conveyor interface is controlled by the PLC system, including the motor of the conveyor. The sorting process begins by placing objects on the conveyor, starting its movement, and allowing objects to pass through the sensor. If the sensor detects an object's height, it continues sorting; otherwise, it halts the process. This step-by-step operation ensures efficient sorting based on height criteria, facilitated by the interaction between the conveyor, sensor, and PLC system.[5]

- Sangeeta Kamboj, Aditi Diwan, Published paper entitled as "DEVELOPMENT OF AUTOMATIC SORTING CONVEYOR BELT USING PLC" The paper represent the system involves a conveyor belt used for sorting job pieces of various sizes for packaging or shipment. When initiated by pressing a green start button, the conveyor belt moves forward, carrying the job pieces towards a photoelectric sensor. This sensor identifies if the object's height is suitable for further processing. A PLC (Programmable Logic Controller) processes the sensor output, controlling an actuator to either allow the object to pass or discard it using a piston push. This process repeats until a stop red push button is pressed to halt the conveyor belt. The methodology for implementing this functionality is outlined, focusing on motor selection, sensor integration, PLC programming, and actuator control. This system ensures efficient sorting of job pieces by automating the process based on height criteria, enhancing productivity and accuracy in the manufacturing environment.[6]

- Kadiyam Sasidhar, Shaik Faiz Hussai, Syed Ali Safdar, Mohd Aleem Uddin, The published paper entitled as “Design and Development of a PLC Based Automatic Object Sorting”.The PLC-based automatic object sorting machine comprises six cycles: Object Detection, Object Placement on Conveyor Belt, Conveyor Start, Sensory Detection, and Sorting Mechanism. It aims to streamline industrial sorting processes by replacing multiple conveyor belt systems with a single conveyor belt equipped with PLC and sensor modules. By detecting objects and sorting them accordingly, the project significantly reduces operational, labor, and installation costs in various industries like food processing and brick manufacturing. This efficiency is achieved with minimal additional inputs for the PLC module. Now, let’s delve into the detailed analysis of each module required for the project.[7]

METHODOLOGY

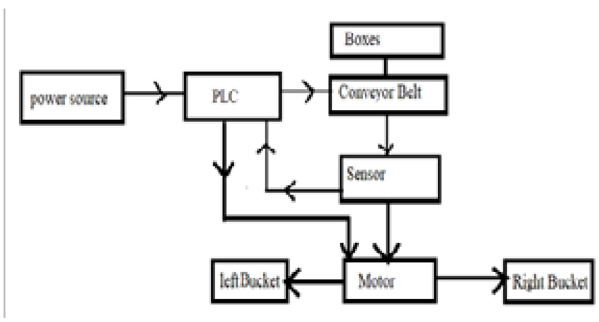


Fig.1. Block Diagram of Overall System

- The illustration above demonstrates the way the basic, step-by-step sorting process functions. The boxes that require to be sorted are initially placed on the conveyor, afterwards which the process will begin. The boxes will be placed onto the conveyor. An ultrasonic sensor is mounted at a particular height. A motor will be commanded to run in a clockwise direction via the PLC if the ultrasonic sensor recognizes a large size box. In the scenario that the ultrasonic sensor detects a box of small size, the PLC will notify the motor to make a turn in the opposite direction. The boxes will be grouped proportionally to the variability in height in this order.

PROPOSED SYSTEM

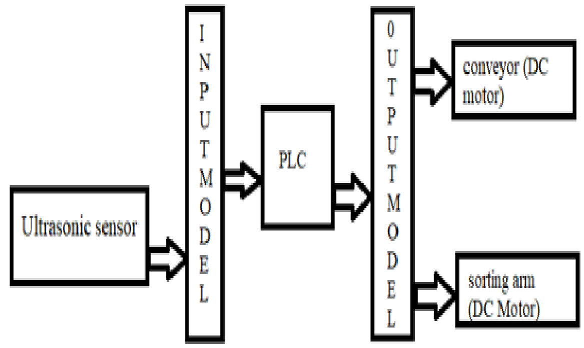


Fig 2. Proposed illustration of overall System

The conveyor system and PLC must be linked in order to function properly this box sorting system. PLC, output module, and input module make up the majority of it.

- Input Module: An ultrasonic sensor is a component of the input module. The height of boxes can be identified by use of these ultrasonic sensors. The PLC gets the ultrasonic sensor’s output and classifies the boxes according to their height margins.
- PLC: Utilizing ladder logic, a programmable logic controller (PLC) regulates every part of the system. Ladder logic is a programming strategy for PLCs.
- Output Module: Two gear DC motors compose the output model. A second gear DC motor is used as a sorting arm, and a first gear DC motor operates a conveyor belt. It will organize the box according to how tall every individual is. The DC motor changes clockwise if the height of the boxes is greater than the ideal amount and reverse if the height of the boxes is less.

COMPONENTS:

The main components required for a system are:

- Programmable Logic Controller
- Ultrasonic Sensor
- Gear DC Motor
- Motor Driver
- Conveyor belt

Programmable Logic Controller

It is PLC that mounted on Zero PCB board .The PLC mainly contain 5 sections. These sections are:

- Power Circuit: It includes a Step-Down Transformer and a full wave bridge rectifier circuit. Step down Transformer converts a 230V AC voltage supply into a 12V AC supply.
- Voltage Distribution: It includes voltage regulators 7805 and 7812, which regulate 5V DC voltage and 12V DC voltage.
- Switching Circuit: It consists of an 8 channel relay module, which acts as a switch for output modules.
- USB to TTL Converter: This module transfers computer data to TTL devices such as Microcontrollers, sensors etc.
- .Microcontroller: This consists of an atmega328p microcontroller, and stored ladder logic to store the whole sorting system.

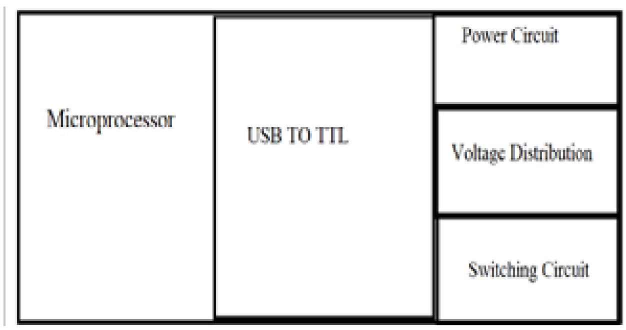


Fig 3. Sections of PLC

Ultrasonic Sensor

Fig.4. Ultrasonic Sensor

This is a device utilized for detecting height of boxes. It uses higher sound wave frequencies than the human audible range to detect the distance of objects. It mainly consists of two parts, the transmitter and receiver, in which the transmitter emits waves and the receiver detects those waves after they strike objects.

Gear DC Motor

Fig. 5 DC gear motor

It is a type of electric motor. It is a device used for sorting purposes, in which it rotates anticlockwise and clockwise. It reduces speed and increases torque. It consists of the DC motor coupled with a gear mechanism to get proper torque and speed characteristics for different applications like some machinery, automation etc.

Motor Driver

Fig. 6 Motor Driver

It is electronic device used for controls the speed and movement of an electrical motor. It clarify signal from microcontroller, sensor to modify the motor behavior respectively.

Conveyor belt: It mechanical system use for transfer boxes one point to another point.

PLC LADDER DIAGRAM

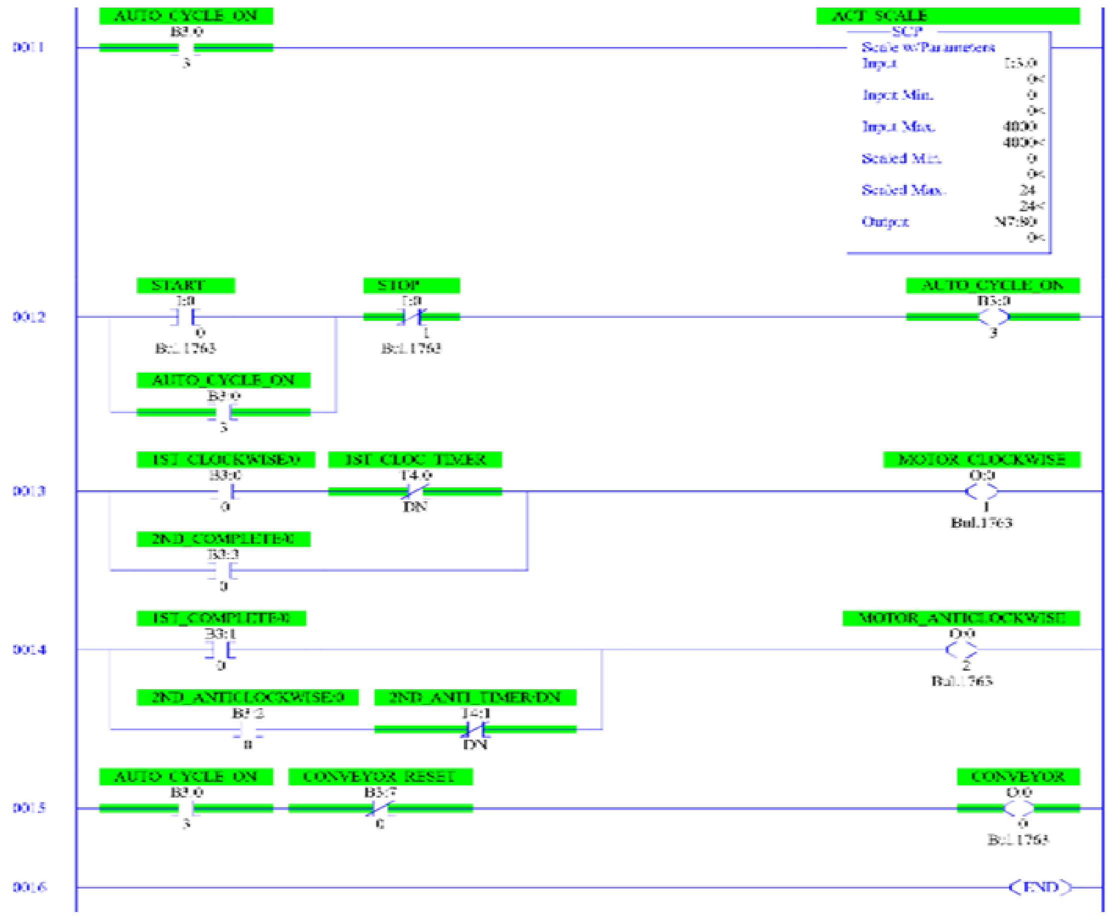


Fig.7 Ladder Logic

RESULT AND ANALYSIS

Table.1 Result and Analysis

Sr. No	Height (cm)	Sorting Condition
1	Below 10 cm	Short
2	10 cm or Above 10 cm	long

In this table, two heights of boxes are mentioned. As per this sorting process is done. Ultrasonic sensors are placed on the conveyor belt. Height of boxes values set in ladder logic, with the help of this ultrasonic sensor identify height of boxes. If the height of boxes is below 10 cm, then it is considered as small boxes, and if boxes are 10 cm or above 10 cm, then it is considered boxes as long boxes.

CONCLUSION

In this system, with the help of PLC (Programmable Logic Controller), boxes are separated by their particular height. This system is less time-consuming and cost-effective. It is an increased profit with the help of time-consuming and high-accuracy features. It also reduces labors work and their monthly expenses. This system can further improve with the help of measuring the weight of objects and sorting objects accordingly to their weights.

REFERENCES

1. Nilima Bargal, Aditya Deshpande, Rucha Kulkarani, Rucha Moghe, designed "PLC Based Object Sorting Automation".in International Research Journal of Engineering and Technology Volume:03 Issue :07 July-2016.

2. A. Gohulakrishnan, P. Balamurugan, N. H Ariharan, T. Dhanushvighesh, N. Santhanakrishna, designed "PLC Based Sorting Operating Using Conveyor System" in International Journal of Advanced Research in Basic Engineering Sciences and Technology Volume 5, Issue 4 , April 2019.

3. Amey Karode, Pranav Mahajan designed "Objects Sorting Machine Using Arduino-Uno" in International Research Journal of Engineering and Technology, Volume: 6, Issue: 04 April 2019.

4. K. Amirtha, V. Girija, S. Preethi, S. Pradeep, designed "Automatic Sorting System By Using PLC" in ISSN :2393-9141.

5. P. Thirumuurugn, R. Aravind, M. Arun Kumar, S. Dharshan Manjunath, R. Kalaiselvan, "designed Automatic Sorting in process Indurtries Using PLC" in Global Research and Development Journal for Engineering, Volume for Engineering, Volume 3, Issue 3 February 2018.

6. Sangeeta Kamboj, Aditi Diwan, designed "DEVELOPMENT OF AUTOMATIC SORTING CONVEYOR BELT USING PLC" in International Journal of Mechanical Engineering and Technology, Volume 10 , Issue 08, August 2019.

7. Kadiyam Sasidhar, Shaik Faiz Hussai, Syed Ali Safdar, Mohd Aleem Uddin, designed "Design and Development of a PLC Based Automatic Object Sorting" in International Jornal of Research and Scientific Innovation, Volume 4 , Issue 12, December 2017.

Enhancement of P&O Algorithm using SEPIC Converter for Drift Avoidance in Solar PV Systems

Yogesh Katdare
yogeshkatdare221@gmail.com

Priti Sathe Bhole
priti.sathe@vpmmpcoe.org

Minal Sathe
minal.sathe@vpmmpcoe.org

Department of Electrical Engineering
VPM's MPCOE
Velneshwar, Maharashtra

ABSTRACT

Solar MPPT algorithms are crucial for optimizing energy extraction from PV systems, yet face challenges in accurately tracking the MPP under changing environmental conditions and load characteristics. This paper emphasizes the need for continual modifications to enhance algorithm performance and adaptability, considering factors like irradiance variations, temperature fluctuations, and partial shading effects. It explores shortcomings of conventional techniques and analyzes recent advancements in MPPT algorithm design to address evolving requirements in PV system architectures and environmental dynamics.

KEYWORDS : *Solar panel, Drift, Modified P&O, Step size, MPPT.*

INTRODUCTION

The increasing demand for sustainable energy has driven widespread adoption of photovoltaic (PV) systems, highlighting the importance of maximizing energy extraction efficiency through effective Maximum Power Point Tracking (MPPT) algorithms. Traditional MPPT techniques like Perturb and Observe (P&O) face challenges in accurately tracking the Maximum Power Point (MPP) under dynamic environmental conditions, partial shading, and system non-linearities. These constraints necessitate continual enhancements to MPPT algorithms to meet evolving demands, considering factors such as irradiance variations, temperature fluctuations, and emerging PV system architectures.

The research aims to address these challenges by reviewing existing MPPT techniques and exploring recent advancements in algorithm design. By evaluating the limitations of conventional approaches and identifying promising avenues for improvement, the study seeks to develop adaptive and intelligent MPPT algorithms capable of maximizing energy yield and enhancing PV system performance across diverse operating conditions. Through empirical analysis and simulation studies, the research endeavors to contribute to renewable energy optimization and facilitate the transition towards a greener future.

SEPIC Converter & Its Components Ratings

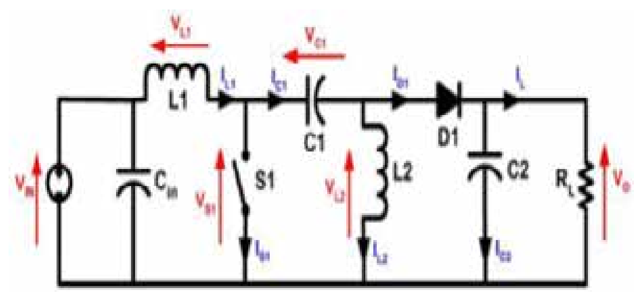


Fig. 1 SEPIC converter

Single-ended primary-inductor converter, is a versatile DC to DC converter capable of both stepping up and stepping down voltage levels. While similar to a buck-boost converter, the SEPIC offers distinct advantages: it handles higher MOSFET and diode voltages and currents, features additional energy storage components, allows for load current to be carried by both capacitors and the source, and permits straightforward isolation. These characteristics make the SEPIC converter a preferred choice in various applications requiring efficient voltage regulation and flexibility in power management.

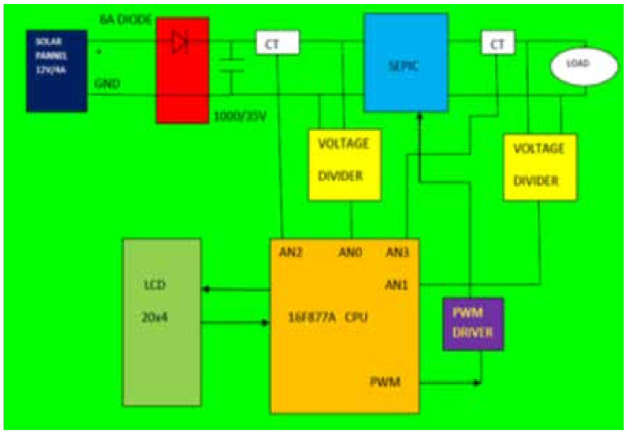


Fig. 2 Block diagram of hardware

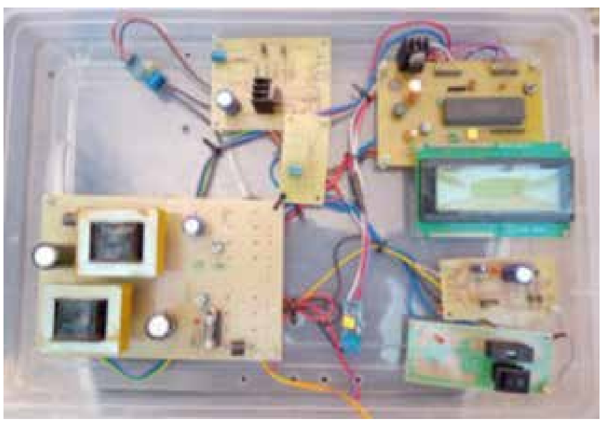


Fig. 3. Hardware set-up

The hardware underwent testing under both no-load and on-load conditions, with a 200 Watts lamp serving as the external load connected to the SEPIC converter. During the no-load operation, the SEPIC converter was active, drawing input power from the solar panel but without any external load connected across it. Results obtained under this condition are summarized in Table 1, providing insights into the converter's performance when operating without a load connected.

Table 1. Results

Sl No	IV (V_{in})	OV (V_{out})	C1	C2	IP	OP	Efficiency
1	20.2	14.6	0.08	0.31	422	151	87%
2	20.5	14.7	0.13	0.31	422	226	87%
3	20.2	15.3	0.13	0.27	371	226	89%

During on-load operation, the output load is connected across the input, resulting in measurable efficiency, unlike the no-load condition where efficiency is zero. Capacitors C1 and C2 exhibit higher values during on-load operation compared to no-load, attributed to their charging and discharging cycles under loaded conditions.

LCD readings during on load operation

CONCLUSION

This paper presents a modified Perturb and Observe (P&O) MPPT algorithm aimed at mitigating drift in solar PV systems by incorporating a checkpoint for change in current (dI). The algorithm effectively overcomes drift-related issues. Using a SEPIC converter with direct duty ratio control offers advantages in power regulation. Validation via MATLAB/Simulink and hardware implementation confirms the algorithm's ability to accurately track the maximum power point, enhancing solar PV system efficiency and potentially reducing carbon footprint, contributing to environmental sustainability.

REFERENCES

1. Muralidhar Killi, Susovon Samanta, , "Modified Perturb & Observe MPPT algorithm for drift avoidance in Photovoltaic systems" 2015 IEEE.

2. Mohammed A. Elgendy, Bashar Zahavi, David J. Atkinson, "Assessment of perturb and observe MPPT algorithm implementation techniques for PV pumping applications", IEEE, January 2012.

3. BOC Group, Operngasse 20b, Vienna, Austria, "An improved perturb & observe MPPT algorithm with variable step", Scientific Bulletin of the Electrical Engineering faculty, ISSN 2286-2455, [2017].

4. Dezso Sera, Remus Teodorescu, Jochen Hantschel, Michael Knoll, “optimized maximum power point tracker for fast changing environmental conditions,” IEEE, July 2008.

5. Nicola Femia, Giovanni Petrone, Giovanni Spagnuolo, Massimo Vitelli, “Optimization of Perturb and observe maximum power point tracking method,” IEEE, July 2005.

6. Luigi Piegari, Renato Rizzo, Ivan Spina, Pietro Tricoli “An optimized adaptive perturb and observe maximum power point tracking control for PV generation”, Energies 2015, 8, 3418-3436, ISSN 1996-1073 [2015].

7. Jehun Hahm, Euntai Kim, Heejin Lee, Changyong Yoon, “A modified Perturb and Observe sliding mode Maximum Power Point Tracking method for PV system under partially shaded condition”, International Journal of Fuzzy Logic & Intelligent Systems, December 2016.

An Ionic Thruster for the Application of Spacecraft

Gauri Joshi*
Assistant Professor
Department of Electro. & Tele Communication Engg.,
VPM's Maharshi Parshuram College of Engineering
Velneshwar, Maharashtra
✉ gauri.joshi@vpmmpcoe.org

Shubham Shete, Ganesh Bamane
Suraj Gamare
Department of Electrical Engineering
VPM's Maharshi Parshuram College of Engineering
Velneswar, Maharashtra
✉ sheteshubham552@gmail.com

ABSTRACT

Ion thrusters are highly efficient propulsion systems, offering significant advantages over conventional methods. They generate high specific impulse, reducing fuel demand. Used for various missions like satellite station-keeping and deep space exploration, they outperform chemical propulsion. With no moving parts and minimal emissions, they operate silently. By applying high voltage, they create an ionic wind for thrust. The Biefeld-Brown effect may enhance aircraft lift.

KEYWORDS *: Ion thrusters, Specific impulse generation, Chemical propulsion system, Orbit station keeping, Ionic wind, Propulsion systems.*

INTRODUCTION

An ion thruster is an electric propulsion system that uses propellants to generate energy. The idea of ion thrusters was first proposed by Robert Goddard in the 1920s, but it was not until the 1960s that the technology became advanced enough to be tested in space. The first successful ion thruster was developed by Harold R. Kaufman and John Brophy at NASA's Glenn Research Center in the 1960s. This first version of the ion thruster uses mercury ions as a propellant to create small amounts of thrust.

In the 1970s, NASA developed a commercial ion thruster called the NSTAR (NASA Solar Technology Application Ready) ion thruster. This thruster uses xenon ions as energy and was used on the Deep Space 1 spacecraft in 1998. In 2000, the European Space Agency developed the High-Power Electric Propulsion System (HPEPS), which uses a similar ion thruster design based on NSTAR but is more powerful. and efficient. HPEPS was used on the SMART1 spacecraft, which orbited the moon from 2004 to 2006. Today, ion thrusters are generally used in spacecraft for space storage and orbital elevation operations. They are also being studied for their potential use in communications operations because they are more effective than chemical weapons and can operate for long periods using small amounts of equipment.

Electric propulsion is a device designed to produce power through rapid exhaust, reducing the amount of electricity required for a particular purpose or application compared to other methods. A reduction in energy consumption can reduce the mass of the launch vehicle or satellite, thus reducing the cost of using a smaller vehicle to deliver the required mass to the orbital target or deep.

In general terms, electric propulsion (EP) covers all drive systems that use electricity to increase engine output. There are many merits for electric thrusters, but the purpose and implementation plan generally relate to thrust, specific thrust, and overall efficiency, which relates to thruster performance relative to changes in thrust and mass during spacecraft speed.

LITERATURE REVIEW

[1] This article presents the most basic information about electric propulsion systems, in this article, scientists discuss the history and types of propulsion systems. This database includes many books from the 1960s and many journal and conference papers published over the years discussing the issue of the aging of electric thrusters,

their quality, physics, and the evolution of technology. Much of this work is based on research on different types of thrusters and development programs in the laboratory. As a result, the basic understanding of how thrusters work often lags behind technological progress and the use of thrusters in space. This article discusses and explains how modern ion and Hall thrusters work by explaining the physics of these devices.

[2] This paper concludes that corona discharge devices generate ion wind and thrust force when an electrical corona discharge occurs between the smart electrode and the large radius ground electrode. The purpose of this study is to examine whether this thrust force can be adjusted to a satisfactory value for aircraft thrust. Preliminary experiments show that the observed competition is equal to that of the air ion. Various types of high-voltage electrodes have been tested, including wires, blades, and needle arrays. The pin sequence was found to be the best. Parametric experiments and theory show that the thrust per unit of power will increase from an early 5 N/kW to almost 50 N/kW, but only by reducing the thrust generated and causing voltage data. In addition to using DC voltage, activation with and without DC bias is also controlled. The results are unclear as to whether this is helpful. The conclusion is that corona discharge is unlikely to be used for piloting.

[3] This article concludes that the new indoor drone called the ion drone, has no moving parts and uses only high-energy electrical currents for propulsion. The power ratio at different input voltages, such as thrust, is obtained by experiment. The researchers proposed a simple model to explain the physics of controlling the energy-generating mechanism of the ion car.

[4] This article describes a high-voltage driver for a radio ion thruster—loads such as heavy ion plasma place strict dynamic demands on power converters. A discrete time-state space model of the power unit of the two high-voltage generators forming the drive system was derived. Report the control's frequency response to the output transfer function and the potential for short circuits encountered.

[This article provides information on the speed-to-power ratio of ion wind propulsion. A pair of asymmetric electrodes can generate ion wind and thrust under pressure. This phenomenon was discovered by Brown in the early 1920s and is known as the Belfield-Brown effect. Proposed as an alternative to today's standard aircraft propulsion, electricity can accelerate ions in the air. The main advantage of the all-electric drive concept is that it has no moving parts, quiet operation, and no combustion emissions. MIT completed the first flight of a state-of-the-art propulsion aircraft based on ion wind in 2018. The proof-of-concept aircraft has a wingspan of 5 m and performs many stable flights. 45m takes about 10 seconds. respectively. The future challenge is to increase the power ratio of ion wind propulsion for electric aerodynamic aircraft. Experimental studies carried out on different EAD thrusters with electrode spacing up to 80 mm showed a maximum thrust of 220 mN/m and a thrust-to-power ratio of 8.9 N/kW of 100 mN/m thrust [5-7].

METHODS AND MATERIAL

Electric thrusters are generally defined by the method of acceleration used to create thrust. These methods can be divided into three groups: electrothermal, electrostatic, and electromagnetic methods. The most common types of EP propellants are described below.

Resist Jet

A resist jet is an electronic device in which the generator is heated by a heating chamber or by passing it through a heat exchanger before entering the rivers. The increase in exhaust gas is due to the heating of the generator, which is limited to two low levels (<500 seconds).

Arc Jet

An Arc jet is also an electrothermal thruster that heats the propellant by passing it through a high-current arc based on a nozzle-feeding system. Although there is an oscillation on the way, the effect of blood on the gas is not significant due to the weak ionization resistance. For simple storage devices, the heating time is only less than 700 seconds.

Ion Thrusters

Ion thrusters use a variety of plasma generation techniques to ionize most of the propellant. These thrusters then use negative gates to electrostatically remove ions from the blood and accelerate them at voltages up to 10 kV or higher. Compared to other types of thrusters, ion thrusters have the best efficiency (from 60% to >80%) and are very powerful (from 2000 seconds to over 10,000 seconds).

Hall Thrusters

This type of electrostatic thrusteruses shears defined by the Hall effect to produce blood. An electric field created by the application of a magnetic field electrostatically accelerates the ions to a high oscillatory rate, while the transverse magnetic field suppresses electron motion, which tends to clear the electric field. The efficiency and specific impulse of the Hall thruster are slightly lower than those obtained with the ion thruster, but the power for the delivered power is higher and the equipment is simpler and requires less energy to operate. A resistor is an electronic device in which the generator is heated by a heating chamber or a heat shield before entering the water stream. The increase in emissions is due to the heating of the generator, which limits the ISP to a low level (<500 s).

Basic Principle of Ion Movements

When high voltage is applied to sharp-edged and smooth electrodes consisting of atoms, ions begin to move. Each atom has an equal number of positive protons and negative electrons. Therefore, these atoms are electrically neutral.

The smart edge terminal is connected to the +ve end of the power supply, and the electrons in the atomic shell are pulled out so that there are more +ve protons in the smart edge terminal. Edge electrode -ve compares electrons. Therefore, the atoms at the tip of the sharp edge become + charged. Similarly, a smooth object (electrode) is connected to the -ve source and excess protons go to the -ve electrode. Negative electrons are more than positive ones. The smooth electrode is very electric. However, other atoms in the air between the electrodes are also involved. These atoms have +ve protons and negatively charged electrons. The electric current near the edge of the electrode is strong enough to attract electrons from the atoms, indicating that the direction of movement of the electrons can be determined by the polarity of the charge (as opposed to the charges repel each other), i.e. -and Just as the charges on the positively charged electrode repel each other, the electrons are simultaneously attracted, so the negative electrons are attracted by the charged electrode. is pushed. Make the atom (near the sharp edge of the electrode) have more +ve protons than -five electrons, so the atom has + force and the charge is unbalanced, hence it is called an ion and is repelled by the strongly charged electrode. and When attracted to the charged electrodes, nothing here so far causes a repulsive force, all forces in both directions are equal and there are no other effects.

But there are other people involved here. In the atmosphere near the more uniform electrode, where the electric field is weak, there are many atoms with the same number of protons and electrons; They are called neutral atoms because they are neutral and do not react. They don't act on anything—a convenient way to connect to a loaded object. When one of the +ve ions collides with this neutral atom, we will have enough energy to hit an electron attracted by the +ve highly charged electrode, and we will make another +ve ion move for a highly charged electrode (because one of the electrons escapes from the atom and becomes a +ve ion) this will lead to an ion.

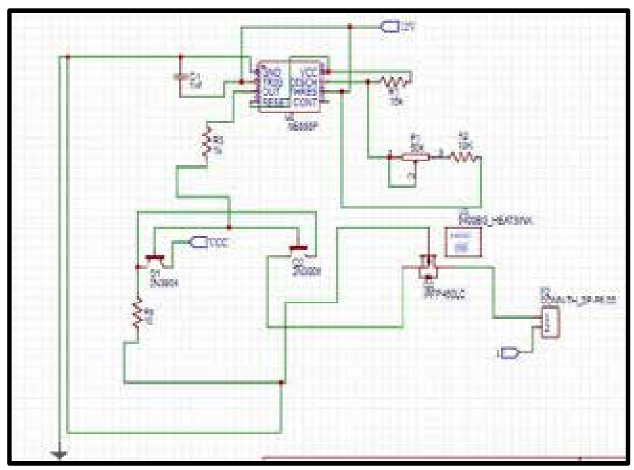


Fig.1: High Voltage generation circuit

The above figure shows a high voltage generation circuit, in that instead of using any microcontroller to generate a square wave we use a 555 timer IC in an a stable Mode. It requires a couple of components but does not require any program. The 50K ohms resistor is a threshold pin to set the frequency of the PWM signal.

As per the datasheet, the output voltage of this IC is adjustable (from 6V to 18V) but the output current is too small (200mA) to generate high voltage using an EHT transformer, so a MOSFET and a simple transistor amplifier we are used to providing a higher current (2Amps) through the primary winding of the transformer.

For convenience, we further classified the above circuit into 3 parts:

I. Oscillator Circuit

II. B-Class Amplifier

III. EHT Driver

The above circuit is known as an oscillator circuit. For this we use a 555 timer IC in Multi- vibrator mode in which a resistance is connected between the supply and discharge pin off the IC. Further, a variable resistance is connected to the threshold and discharge pin so that by changing the pot value the output will be changed. A multi-vibrator circuit is nothing but a switching circuit that generates non- sinusoidal waves such as square waves, and rectangular waves.

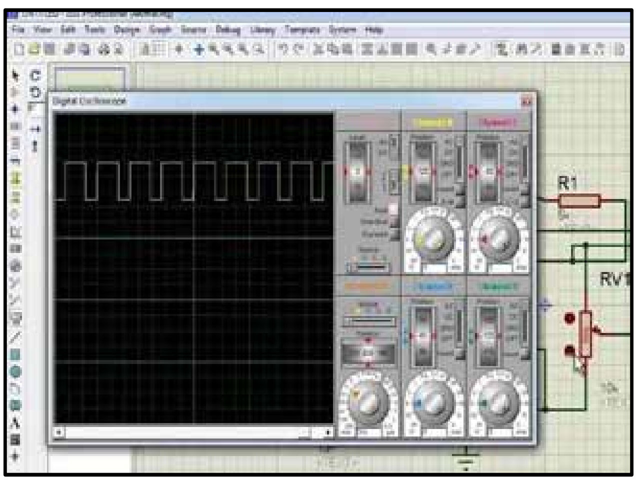


Fig. 2: Output waveform

The high voltage module is built on the Tesla coil principle, and the high voltage pulse produces high voltage current. It is small, high-performance, and has simple electrical equipment (just connect the switch and battery).

Body volume: length 56 * diameter 24 * Cutting diameter 21 mm (measured with precision Vernier caliper) Input parameters: 3.7-6V 4A Input line length: 10 cm Output parameters: 400KV 0.5A Line length: about 8 cm

About power supply: You can use two wires, such as a 3.7V lithium battery or 18650 battery, the mobile phone is not powered (remove the protective plate, the recommended capacity is more than 2000mAh) or nickel-cadmium/nickel metal hydride battery, 4V or 6V lead- acid battery, etc.

Type Red line is the quality of the power supply, output 2. High-temperature and high-temperature resistant silicone wires resistant silicone metal

Multitapping Transformer

A multi-tap transformer is a step-up or step-down transformer with multiple taps on the primary or secondary winding that can adjust the volts/turn ratio. This allows the transformer to compensate for line drop and percentage voltage regulation. Multi-tap transformers provide flexibility in input and output voltage requirements are some 1.5V, 3V, 6V, 9V, and 12V transformers with multiple taps:

1.5V 3V 4.5V 6V 7.5V 9V 12V 3Amp Bridge Tapping Step Down Transformer: This transformer has an input of 220V to 240V AC and weighs 1050 grams.

1.5V 3V 4.5V 6V 7.5V 9V 12V 750MA Output Step Down: This transformer provides close to rated voltages on the higher side and doesn't heat up or vibrate.

FABRICATION OF IONIC THRUSTER

This is a prototype model of an ionic thruster. This device is used to create a thrust for spacecraft in space with a lesser amount of propellant and high voltage. In our prototype model, we are not using a propellant because of its high cost but we use extremely high voltage which goes around 30KV to 40KV, since we work with high voltage, is a dangerous circuit so be careful.

Table1:Hardware specification

Sr. No.	Name of components	Specification	Quantity
1	Acrylic Sheet	(4*2)ft,2MMthick	1
2	Brass Tubes	10Ft,6MMOD	1
4	MS Threaded Rod	150 MM long, 8 MMOD	4
5	MS Bolt	8MM	48
6	Double Insulated Wire	1Sq.mm,3M	1

The below figure shows the 2D CAD model of positive and negative grids. The selected material is a 2MM thick Acrylic Sheet because we aim to make a model with lower weight and as we are dealing with high voltage an acrylic material has a good capability to handle such high voltages without any burn marks on it.

As we are not using a propellant, the output thrust is quite low and hence, we reduce the thrust area outlet. It has a cylindrical shape with OD (outer diameter) of 100MM only. On the edges of each grid, four 8MM holes are made to stack all plates.

The specific details of the fabrication process depend on the type of ion thruster being manufactured, as well as the specific requirements of the mission. However, all ion thrusters involve the creation of plasma, acceleration of ions, and the expulsion of the ions to generate thrust.

We are using an acrylic sheet of 3mm to make a structure because it is lighter in weight than the plywood and has good electrical resistance so that it will avoid spark discharge between high voltage grids. The thrust outlet is circular so we use an Orbital Bit having an adjustable diameter setting. For our project, we selected 100mm of internal diameter and outside we selected a square shape because it is easy to cut.

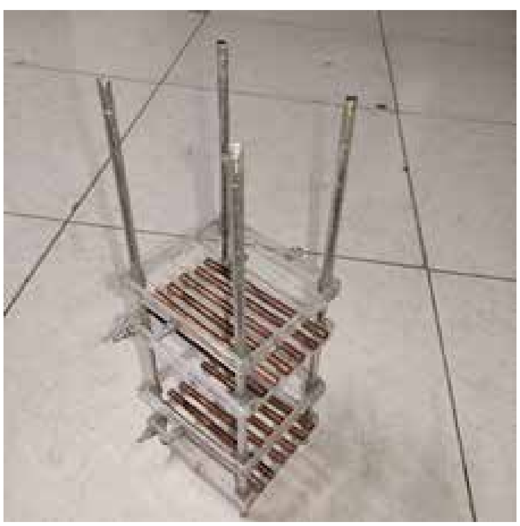


Fig.3 : Stacking the stages.

As we are making the three stages so that it has a total of 6 plates. We need to stack all 6 states whose negative and positive electrode needs to beset parallel. For staking we use 4no's,8mm mild Steel (MS) bolts. But using an acrylic tube is a very good choice because of its lighter weight and prevents short circuits but unfortunately, we are unable to find an 8mm acrylic tube so we go with an MS tube.

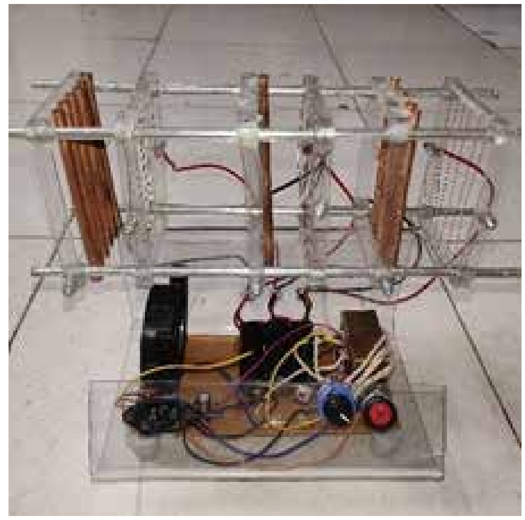


Fig.4: Actual picture of Thrust Outlet

RESULT

Applying a high voltage across the grid and adjusting the distances so that only a glow discharge will occur, if a spark discharge occurs then no thrust will get at the output.

CONCLUSION

While making this project different types of propulsion systems are understood, and which is the most suitable engine for deep space research. In electric thrusters, DC high voltage is the essential requirement, and we have a great chance to learn the circuitry of how to generate DC high voltage—also finding out the reason electric thrusters are only useful in a space.

At the start decided to make a fuel-powered (xenon) electric ion engine so all the necessary information could be gathered and required components where they are found, but most of the components are not available in India and their cost is too high and a precise machinery and laboratory is required to make a fuel power engine.

Instead of changing the idea we decided to make a base model of the engine that works on atmospheric conditions and successfully made a prototype model of the Ionic thruster. Since there is no fuel, it cannot be able to pull the huge satellite, but the base model successfully demonstrated the practical working of electrostatic ionic thruster.

REFERENCES

1. D.M. Goebel,I. Katz, "Fundamentals of Electric Propulsion: Ion and Hall Thrusters," JPL Space Science and Technology series, 2008.
2. Jack Wilson, Hugh D. Perkins "An investigation of Ionic Wind Propulsion" Glenn Research Center Cleveland, December 2009
3. Chor Fung Chung, Wen J. Li, "Experimental studies and parametric modeling of Ionic Flyers", The Chinese University of Hongkong, August 2007.
4. F. Belloni, R. Grossi, P. G. Marnessi, "HV Drivers for Ion Thrusters." University of Milano Italy IEEE Conference, 2007
5. Uwe Schichler, "Investigations on Thrust-to-Power of an Ionic Wind Propulsion", Institute of High Voltage Engineering and the System Performance Graz University of Technology IEEE Conference 2020.
6. Ho Shing Poon, Mark K. K. Lam, Maxwell Chow, and Wen J. Li. "Indoor Ionic Propulsion Technology High Voltage Power System Design" IEEE Conference 2008.
7. Website:"https://www.nasa.gov/centers/glenn/about/fs21grc.html"NASA-Ion Propulsion.

Intelligent Charging Management of Electric Vehicles for Smart City

Minal Dilip Sathe, Priti Sathe, Varada Kolge
Assistant Professors
Department of Electrical Engineering
VPM's MPCOE
Velneshwar, Mumbai University, Maharashtra
✉ minal.sathe@vpmmpcoe.org
✉ priti.sathe@vpmmpcoe.org
✉ yogesh.katdare@vpmmpcoe.org

Varada Kolge
Department of Electronics & Telecommunication Engineering, Gharda Institute of Technology
Lavel

Samrudhhi Waje
Dept. of Electronics & Telecommunication Engg.
Sharadchandra Pawar College of Engineering,
Dumbarwadi, Otur

ABSTRACT

The increasing prevalence of Electric Vehicles (EVs) on the roads has led to a corresponding rise in emissions from transportation, causing environmental and health concerns. Electric transportation offers a solution by emitting fewer pollutants during operation. However, a significant challenge for EVs is the availability of suitable refueling options compared to Internal Combustion Engine Vehicles (ICEVs). This research introduces two refueling approaches: Electric Vehicle Charging Stations (EVCS) and Electric Vehicle Battery Swapping Stations (EVBSS). Both methods involve either recharging the EV through grid connection or swapping the depleted battery with a charged one. Charging management strategies are assessed under decentralized and centralized control in a multi-aggregator setting. The study includes recommendations based on the results.

KEYWORDS *: Wireless power transfer, Electric vehicle, Wireless charging, Environmental impact, Energy efficiency.*

INTRODUCTION

Advancements in technology, coupled with population growth and the expansion of amenities, are paving the path toward an elevated lifestyle and improved quality of life. The global trend is moving towards increased connectivity among various elements to enhance existing facilities and promote better living conditions for all citizens. This shift is gradually steering towards the development of Smarter Cities, emphasizing interconnected and sustainable urban growth.

Smart City Development

Smart City development focuses on practices in different parts of our society that are sustainable and have as little as possible negative impact on the environment [1]. Fur- thermoses, the development is citizen centric, i.e. the opinions, concerns and the feedback of the citizens is of prime importance in bringing about changes in the society. A city's"smartness" is not only reflected in its technology but also by its people [2]. The term 'Smart citizens' refers to a population that takes informative and sustainable decisions for the betterment of their current conditions. A primary feature of Smart Cities is the utilization of advanced Information and Communication Techniques (ICT) for addressing challenges that are present in the city. Broadly classifying, Smart City Development may be sectioned into the following segments:

• Smart Living - Relates to the overall living conditions of the people. The techno-orgy remains interconnected leading to easier and better living conditions. [2] Smart Living is focused on better health care, safety and education [3].

• Smart Mobility/ Transportation - Smart mobility refers to improvements in the mode of transportation that stays away from using petrol and diesel based vehicles as they release a high particulate emission which is poor for the environment. This further includes improvements in road infrastructure and traffic management. Poor traffic management and road conditions lead to extended time that is spent by the vehicle on the road, and therefore increased emissions [3] [4].

• Smart Energy and Grids The energy sector and the power grid are major components in the quality of life. Smart Energy refers to smarter generation of power from renewable sources as well as conservation and appropriate use of the generated energy. Smart Grid encompasses load management, power quality and reliability management, decreasing losses on the grid, and other power grid related aspects.

• Smart Buildings and Urban Planning - Increased quality architecture and better designs that not only incorporate the growing population density but provides them with healthy living conditions [2] [3]. This includes the development of road networks, green buildings and use of renewable/sustainable material and energy management.

• Smart Governance - Increase in smart communication with the citizens and developmental policies that incorporate the citizen point of view and their needs [3]. Also, policies that encourage sustainability in the growth of the city.

• Smart Economy - Presence of an urban openness and service innovation that allows for economic policies for the betterment of the people [2] [3].

Within each group, the development focusses on sustainable solutions that require active and smart participation from the citizens. The categorization of any city as Smart City involves the development of ICT so as to allow interface between the different aspects for coordination, development and improvement.

The charging management of Electric Vehicles is dependent on several different aspects. This includes the environment in which the scheduling is carried out along with the charging framework that is being employed. Broadly considering, the frameworks are divided into charging and swapping infrastructure. This may of course be further evaluated for other applications of renewable assisted charging and swapping stations. In this chapter, survey of literature focusing on the different frameworks for EV charging management and the environment in which the scheduling is carried out has been presented.

ENVIRONMENT CLASSIFICATION FOR EV REFUELING

The EVCS problem is addressed as an optimization problem that optimizes a parameter based on the scheduling environment of the problem. The environment under which the scheduling taken place may be further classified based on [12] [13]: (i) Scheduling Control (ii) Mobility Parameters (iii) Scheduling Request Time and (iv) Stakeholders.

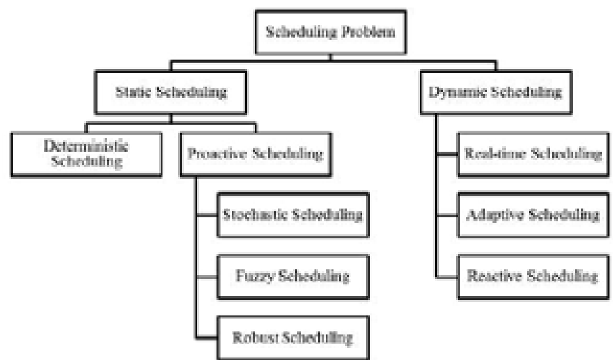


Fig.1

This is summarized in Figure 1 and discussed as follows:

1. Stakeholders - Primarily, three entities are concerned as the major stakeholders in EV charging management problem and are categorized as follows:

i) Power Grid

ii) EV Owner

iii) Service Provider/ Aggregator

2. Mobility Parameters - Mobility Parameters for any vehicle are related to its geo- graphical location and trip details [14] [15]. It includes the source/ destination of travel, the route that is being taken, the time of departure from the source and the tentative time of arrival at the destination. If a charging station is on the route of the EV, then the State of Charge (SOC) level will drop from the time when the request was made by the time the EV reaches the charging station.

Inclusion of mobility parameters, or mobility awareness, implies that this variation in the SOC would be included while scheduling the EV so as to ensure that the appropriate desired SOC levels are met. Static scheduling does not consider the mobility parameters and it based on the initial SOC at the time of the request.

3. Control - Control of the scheduling refers to the entity that finalizes the time and location of scheduling. All scheduling requests are made by the EV owner to the aggregator which schedules the EV. The finalization may be done in two ways [12]:

i) Centralized Scheduling - The aggregator, based on the SOC and other parameters specified of the user, schedules the EV at an appropriate charging station for the required number of charging slots. The mobility parameters may or may not be considered here.

ii) Decentralized Scheduling - Decentralized scheduling may be approached in two different ways (Figure 2.2 (a) and (b)).

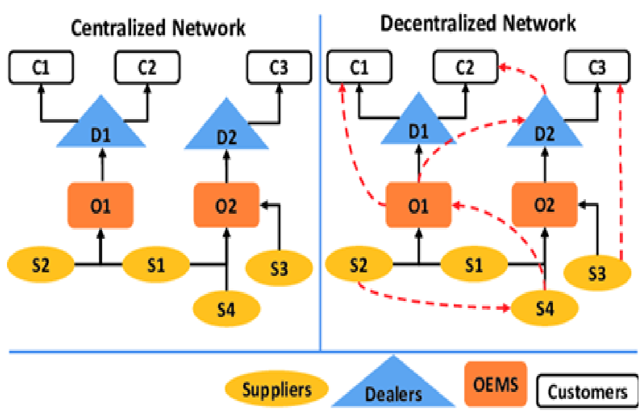


Fig. 2. (a) and (b)

As in Figure 2.2 (a), here the EV driver searches for the appropriate time and location for refuelling. However, this is a complex process and would require a significant devotion of time from the consumer's side. In Figure 2.2 (b), the aggregator determines the possible options for scheduling and communicates them to the consumer, who makes the final choice of the scheduling.

4. Scheduling Request Time - This signifies when the scheduling requests are made and are further classified as [12] [13]:

i) Offline - The scheduling requests are received prior to the start of the scheduling period. The aggregator receives all requests prior to a set time limit and then schedules all the received requests.

ii) Online - The scheduling requests are received in real-time, which may be during the scheduling period. This offers a more convenient option for EV scheduling, however, is greater in complexity and is more difficult to manage due to the variable times required for recharging by the EVs.

It is observable that as the EVCS problem is approached as an optimization problem, it is important to identify the feature/parameter that is being optimized and in the environment it is being optimized in. Furthermore, as the EV SOC varies with its location with respect to its source and the charging station, it is important to consider the mobility patterns along with the vehicle routing so as to understand the charge depletion of the EV along with traffic related delays that may impact the charging of the EVs.

In the consequent sections, a few of the literature is evaluated with respect to the stakeholders and the framework (charging or swapping that has been utilized). While evaluating the literature with these two key points, other environment particulars have also been explored.

2.2 Frameworks - Charging and Swapping

Two major frameworks may be considered for the management of Electric Vehicles in different stakeholder scenarios. These are Charging and Swapping frameworks.

The EV charging stations are generally classified based on their charging rates as Level 1, Level 2 and Level 3 [16]. A further classification may be included that categorizes the charging station in terms of their location. They are classified as:

i) Residential charging - The EV owner charges at their home/living society. This is accessible to the resident only.

ii) Commercial/ Industrial/ Workplace - In order to promote the use of EVs, a number of commercial and industrial locations have started implementing charging stations at their parking lots so as to allow the EV owner to charge while they are at work or out for entertainment. These are, however, only accessible to employees and/or people that are visiting the commercial complex.

iii) Public Charging Stations - These charging stations aim at mimicking the functionality of the refueling stations for ICEV. They are accessible to all customers.

A comparison of the charging stations based on their location is presented in Table 2.1 [17][18].

In this research, the EVCS problem is addressed and is discussed in the following sections based on different techniques and the environment in which the scheduling is done.

Electric mobility falls under two different sections of Smart Cities. It covers the transportation section as well as the power grid and energy management. The EV operates on the road but requires the power grid for recharging.

Various charge scheduling techniques have been employed to optimize charging costs and off-peak charging activity [6], as well as to understand charging patterns based on user behavior [7]. These techniques include first available scheduling (FAS), random and first available scheduling (RFAS), greedy local search, Simulated Annealing, and heuristic algorithms. Linear programming approaches have been used to implement decentralized scheduling in order to reduce consumer pricing costs [8]–[9]. Research has been done on the effectiveness of mobility-aware scheduling, comparing static and dynamic scheduling [10], examining the influence of EV arrival times [11], and utilizing mobility patterns to execute recharge scheduling [12]. Scalable scheduling has been achieved by the use of Monte Carlo [14], a cooperative distributed method, and a multi-agent strategy [13].

Aggregator and customer advantages are traded off in the process of optimizing stakeholder benefits. In order to maximize aggregator profit and minimize charging cost, [15]–[16] make an effort to address the benefits of both stakeholders in a multi-objective manner, where they are able to strike an ideal trade-off. The benefits of all three stakeholders are maximized by a workplace-based charging station [18] and a coordinated charging framework in a multi-aggregator scenario [17]. Moreover, schedule cooperation amongst aggregators has been investigated for profit maximization. A multi-aggregator collaborative scheduling strategy is used by Mukherjee and Gupta [19] in an effort to maximize aggregator profits and the number of vehicles scheduled in offline and online scenarios. Although more EVs were scheduled as a result of cooperation, there was no discernible difference in the profit when compared with the non-collaborative scenario [19].

In [17], aggregators and the distribution system operator (DSO) administer a centralized hierarchical architecture for coordinating PEV charging over several decks in an effort to maximize profits through cooperative charging. The outcomes of collaborative scheduling were somewhat higher. In order to optimize the aggregators' profit through cooperative scheduling and inter-aggregator energy trading (IET), a centralized distributed optimization approach was devised in [20]. Higher profits were obtained with cooperative scheduling that included energy trading. According to the research, collaborative scheduling results in more scheduled electric vehicles (EVs), but no corresponding improvement in profits is seen.

Another framework that may be explored is that of swapping stations. Here, instead of the EV being charged upon its arrival at the charging station, the depleted battery is exchanged with a charged battery [11,19–26]. The depleted battery is then recharged by the service provider at a convenient time. In the swapping framework, the controlling environments may be classified as Centralized and Decentralized along with the benefits of the different stakeholders being optimized. Unlike the charging stations, the literature classifies the BSS as public swapping station only.

However, two different frameworks for BSS may be considered as BSS and CBSS. The first provides the facility of Swapping to the driver and the charging and battery swapping station (CBSS) provides the opportunity to driver to choose either swapping or charging of the EV.

The multi aggregator EV charging station framework is explored for Non- collaborative and collaborative scheduling under centralized and decentralized control. The results are evaluated for aggregator profits and the response of the driver in terms of satisfaction and willingness. Furthermore, routing and PV assisted charging stations are explored to evaluate their efficiencies.

For the different control schemes, the evaluation of the developed URIs, ri and satf showcases the applicability and accuracy of these indicators while evaluating the response of the EV drivers. The results indicate better performance in the decentralized scheduling as compared with centralized scheduling in terms of driver satisfaction and willingness. The profits in NCOs are greater in DES whereas CES exhibits greater profits in collaborative scheduling. An advantage presented by DES is also in the safety aspect

The EV charging station framework, although effective in a public charging application with fast charging capabilities, is still inconvenient for the driver. With consideration for mobility parameters, the majority of requests coincide with peak load hours resulting in numerous EVs remaining uncharged. With limitations of slots to charge, these EVs if scheduled would add a significant load to an already high existing load at those hours. This problem is potentially addressed by a separate framework called as the battery swapping framework.

Battery Swapping Stations Scheduling

The charging management of variable number of charging requests has been attempted at plug-in charging stations that allow the vehicle to be charged upon their arrival at the location in the previous chapter. Where this technology is most frequently deployed, there are significant drawbacks that are encountered by this framework. A major drawback remains the waiting period for the EV driver while the EV recharges. Another challenge is posed in terms of the availability of the appropriately sized land, specifically in densely populated areas, and the load that would be reflected onto the grid, especially with increasing penetration of EVs and/or high population density. As was shown in the results of the previous chapter, as the number of charging requests is increased, the consequent load increases. Furthermore, due to mobility aware scheduling, the timing of the scheduling is important. Since there is variability in the charging duration for each EV due to variations in the SOC, a greater number of EVs may not be accommodated.

- Battery Swapping Station (BSS) - The depleted battery is swapped from the EV and replaced with a charged battery.
- Charging and Battery Swapping Station (CBSS)- Based on the availability of resources and/or driver preferences, the EV may be scheduled for swapping or charging at the swapping station.

The swapping frameworks have been presented in this chapter for an offline scheduling for Single Aggregator and Multi-aggregator in centralized and decentralized control. The Multi-Aggregator framework has further been presented for non-collaborative and collaborative scheduling. The primary stakeholders remain the same as for EVCS and are the grid, EV driver, swapping stations and the aggregators.

This Paper presents the charging management of Electric Vehicles for a large number of scheduling requests to represent higher penetration and/ or EVs in a high population density area. The charging management is carried out in charging station and battery swapping frameworks to maximize the profit of the aggregators. The scheduling environment is multi aggregator, day-ahead and mobility aware. In keeping with the Smart City paradigm, the EV management is carried out with consideration to the preference of the customer while maximizing the aggregator profits. The consequent chapters in the thesis present an exploration of the mentioned frameworks for refueling EVs. A brief overview of the chapters is presented as follows:

PROPOSED SYSTEM

The main contributions of the thesis to the existing literature focus on the development of the single and multi-aggregator non-collaborative and collaborative scheduling environments under different control schemes concerning Centralized and Decentralized approaches. The formulation of the profit maximization incorporates the benefits of the aggregators and also includes the benefits of the EV drivers by the use of User/ Driver Response Indicators proposed and developed in this thesis. The developed indicators are used to evaluate the satisfaction levels and the willingness of the driver to adhere to a particular scheduling. Similar to the EV charging stations (EVCS), Photo Voltaic assisted charging stations (PVCS) are evaluated in non-collaborative and collaborative multi-aggregator scheduling. In the swapping framework, in addition to the option to swap the batteries at battery swapping stations, charging and battery swapping stations (CBSS) are also presented along with the respective profit formulations. A comparative analysis of the different techniques and an overall comparison of the frameworks have been presented. The development of the user response indicators and respective penalty factors to incorporate the benefits of the EV driver while maximizing the benefits of the aggregator is a significant aspect of this work which has been evaluated in different frameworks and control schemes.

CONCLUSION

Based on the developed demand, the objective remains to maximize the profit of the aggregator which is done using two control approaches: Centralized and Decentralized. The EV charging station problem is formulated in these control schemes for multi-aggregator scheduling and is evaluated in non-collaborative and collaborative scheduling. The scheduling is evaluated without and with the inclusion of the driver response in the profit equations. Similar approach is devised and carried out for swapping stations where the scheduling is managed for Battery Swap Stations (BSS) and EV charging and Battery Swap Stations (CBSS). The formulation of the multi-aggregator profit maximization along with the inclusion of driver parameters has been presented in decentralized and centralized control. A comparison in the performance of these two approaches, i.e. EVCS and BSS has been presented and their collective advantages and shortcomings have been discussed. The response of the EV driver has been evaluated for both schemes under centralized and decentralized control.

REFERENCES

1. M. Roscia, M. Longo, and G. C. Lazaroiu, "Smart city by multi-agent systems," 2013 Inter- national Conference on Renewable Energy Research and Applications, pp. 371–376, October 2013.
2. A. Arroub, B. Zhi, E. Sabir, and M. Sadik, "A literature review on smart cities- paradigms, opportunities and open problems," 2016 IEEE International Conference On Wireless Net- works and Mobile Communications, pp. 180–186, October 2016.
3. L. G. Anthopoulos, "Understanding the smart city domain: A literature review," in Trans- forming city governments for successful smart cities. Springer, 2015, pp. 9–21.
4. A. Monzon, "Smart cities concept and challenges: Bases for the assessment of smart city projects," in International Conference on Smart Cities and Green ICT Systems. Springer, 2015, pp. 17–31.
5. United States Environmental Protection Agency (EPA). Global green- house gas emissions. [Online]. Available: https://www.epa.gov/ghgemissions/ global-greenhouse-gas-emissions-data
6. Open Government Data (OGD) Platform India. Total number of regis- tered motor vehicles in india. [Online]. Available: https://data.gov.in/catalog/ total-number-registered-motor-vehicles-india
7. Ministry of Statistics and Programme Implementation, India. Motor vehicles - statistical year book india 2016. [Online]. Available: http://www.mospi.gov.in/ statistical-year-book-india/ 2016/189
8. A. G. Boulanger, A. C. Chu, S. Maxx, and D. L. Waltz, "Vehicle electrification: Status and issues," Proceedings of the IEEE, Vol 99 No. 6, June 2011.
9. V. Gupta, S. R. Konda, R. Kumar, and B. K. Panigrahi, "Multiaggregator collaborative electric vehicle charge scheduling under variable energy purchase and ev cancelation events," IEEE Transactions on Industrial Informatics, vol. 14, no. 7, pp. 2894–2902, 2018.
10. J. C. Mukherjee and A. Gupta, "Distributed charge scheduling of plug-in electric vehicles using inter-aggregator collaboration," IEEE Transactions on Smart Grid, vol. 8, no. 1, pp. 331–341, 2017.
11. Q. Kang, J. Wang, M. Zhou, and A. C. Ammari, "Centralized charging strategy and schedul- ing algorithm for electric vehicles under a battery swapping scenario," IEEE Transactions on Intelligent Transportation Systems, vol. 17, no. 3, pp. 659–669, 2016.
12. J. C. Mukherjee and A. Gupta, "A review of charge scheduling of electric vehicles in smart grid," IEEE Systems Journal, vol. 9, no. 4, pp. 1541–1553, 2014.
13. W. Su, H. Eichi, W. Zeng, and M.-Y. Chow, "A survey on the electrification of transportation in a smart grid environment," IEEE Transactions on Industrial Informatics, vol. 8, no. 1, pp. 1–10, 2012.
14. Y. C. T. Wang, O. Kaiwartya, G. Min, N. Ahmad, and A. H. Abdullah, ""An EV Charging Management System

Concerning Drivers' Trip Duration and Mobility Uncertainty"," IEEE Transactions on Systems, Man, AND Cybernetics: Systems, October 2016.

15. C. Wen, J. Chen, J. Teng, and P.Ting, "Decentralized plug-in electric vehicle charging se- lection algorithm in power systems," IEEE Transactions on Smart Grid, Vol 3, No. 4, pp 1779 - 1789, 2012.

16. W. Su, H. Eichi, W. Zeng, and M.-Y. Chow, "A survey on the electrification of transportation in a smart grid environment," IEEE Transactions on Industrial Informatics, vol. 8, no. 1, pp. 1–10, 2012.

17. US Department of Energy, "Alternative fueling station counts by state." [Online]. Available: https://www.afdc.energy.gov/fuels/stationscounts.html

18. Developing infrastructure to charge plug-in electric vehicles. US Department of Energy. [Online]. Available: https://www.afdc.energy.gov/fuels/electricityinfrastructure.html

19. J. Chen, M. Qi, and L. Miao, "The electric vehicle routing problem with time windows and battery swapping stations," in 2016 IEEE International Conference on Industrial Engineer- ing and Engineering Management (IEEM). IEEE, 2016, pp. 712–716.

20. Vishu Gupta, Srikanth Reddy K, Rajesh Kumar, BK Panigrahi, "Multi-Aggregator Collaborative Electric Vehicle Charge Scheduling (CEVCS) Under Variable Energy Purchase and EV Cancellation Events", IEEE Transactions on Industrial Informat- ics,November 2017

21. Vishu Gupta, Rajesh Kumar, B. K. Panighari, "Electric Vehicle Charging Management- Battery Charging vs Swapping in Densely Populated Environments", IEEE Smart Grid News Letter, October 2019.

22. V. Gupta, S. Konda, R. Kumar, B. K. Panigrahi, "Electric Vehicle Charge Scheduling (EVCS) with PV assistance for variable energy purchased in a multi aggregator environment", IET, The Journal of Engineering, Vol. 2019, No. 18, 2019, 4836 – 4840

23. Vishu Gupta, Srikanth Reddy K, Rajesh Kumar, BK Panigrahi, "Collaborative Multi-Aggregator Electric Vehicle Charge Scheduling with PV Assisted Charging Stations Under Variable Solar Profiles", IET Smart Grid(Online)

Need of Inclusion of Subject Domains Like AI, ML and IoT in the Engineering Curriculum: Vision Industry 4.0 and NEP 2020

Supriya Gupta*
Assistant Professor
Dept. of Computer Science and Engg. (Data Science)
Shri Ramdeobaba College of Engg. and Management
Nagpur Maharashtra
✉ Supriya17gupta@gmail.com

Chandrahas C. Handa
Department of Mechanical Engineering
Professor & Director
Viderbha Institute of Technology
Nagpur, Maharashtra
✉ chandrahashanda@gmail.com

ABSTRACT

As we traverse deeper into the era of Industry 4.0, characterized by the fusion of digital technologies, artificial intelligence (AI), and automation, the transformative potential of AI, machine learning (ML), Internet of Things IoT, etc emerges as a central force. This paper presents a comprehensive examination of the profound impact that AI ML and IoT have on Industry 4.0 across various sectors and applications. Firstly, the paper delves into the foundational concepts of Industry 4.0, elucidating its core principles and technological underpinnings. It then proceeds to explore the pivotal role of AI, ML and IoT within this framework, highlighting their capabilities to drive efficiency, innovation, and agility across industrial processes. The discussion encompasses diverse domains where AI, ML and IoT are revolutionizing operations. In manufacturing, predictive maintenance powered by AI algorithms optimizes machinery uptime and reduces downtime costs. Supply chain management benefits from AI-driven demand forecasting and intelligent inventory management, enhancing responsiveness and minimizing inefficiencies. AI-enabled quality control ensures product consistency and reduces defects, bolstering competitiveness. Furthermore, AI, ML and IoT etc are reshaping the landscape of robotics and automation, enabling the development of autonomous systems capable of adaptive learning and decision-making. In the realm of smart factories, AI, ML and IoT driven analytics harness data from interconnected sensors and devices to optimize production workflows and enable real-time decision support. Even the new Education Policy (NEP) 2020 is looking forward of creating the technical human resource and engineering professionals with multidiscipline knowledge as per the need of Industry 4.0. In conclusion, the integration of AI, ML and IoT etc. into Industry 4.0 heralds a new era of digital transformation, offering unprecedented opportunities for efficiency, innovation, and competitiveness.

KEYWORDS : *Industry 4.0, NEP 2020,AI,ML, IoT, Multidisciplinary education.*

INTRODUCTION

The advent of Industry 4.0 is the need of time for developing India and marks a pivotal moment in the evolution of manufacturing and industrial processes, defined by the integration of digital technologies, automation, and data-informed decision-making. At the heart of this transformation lie artificial AI, ML and IoT, etc, poised to revolutionize how industries operate, innovate, and compete in the global market. Industry 4.0 represents a paradigm shift, transcending traditional manufacturing practices to embrace interconnected the Internet of Things (IoT),cyber-physical systems, and cloud computing. This interconnectedness fosters unprecedented levels of data generation and exchange, optimize processes, and drive autonomous decision-making [1-3].

However, while the promise of AI and ML is immense, so too are the challenges and considerations that accompany their integration into industrial ecosystems. The imperative for addressing ethical quandaries concerning data privacy, algorithmic bias, and the displacement of human labor highlights the necessity of responsible and inclusive deployment strategies. Moreover, the complexity of AI and ML implementations necessitates robust cyber security measures to safeguard against potential vulnerabilities and threats [4, 5].

In light of these opportunities and challenges, this paper endeavors to provide a comprehensive examination of the impact of AI, ML and IoT on Industry 4.0. By exploring key applications, emerging trends, and critical considerations, it seeks to elucidate the transformative potential of these technologies and pave the way for a future of intelligent, adaptive, and sustainable industries [6].

Industry 4.0

Industry 4.0, dubbed the Fourth Industrial Revolution, marks a profound transition in manufacturing and industrial production, integrating digital technologies, automation, and data-driven processes. This paradigm shift merges physical and digital realms, where cyber-physical systems (CPS), the Internet of Things (IoT), and artificial intelligence (AI) converge, creating interconnected ecosystems of unprecedented complexity and capability. This fusion transcends traditional boundaries, empowering industries with enhanced efficiency, agility, and intelligence. Originating in the early 21st century, Industry 4.0 is driven by advances in computing power, connectivity, and data analytics, leading to the emergence of smart &intelligent factories [7, 8]. The five Key pillars of Industry 4.0 generally are

Interconnectivity: IoT devices and sensors enable seamless communication and data exchange among machines, products, and systems.

Information Transparency: Real-time access to data and analytics offers stakeholders unprecedented visibility into the production process, facilitating informed decision-making and optimization.

Technical Assistance: AI, machine learning, and augmented reality empower workers with intelligent tools, enhancing productivity and quality.

Decentralized Decision-Making: Cyber-physical systems autonomously make decisions, enabling adaptive and responsive operations without centralized control.

Modularization: Modular production systems allow rapid reconfiguration and customization to meet dynamic market demands, ensuring flexibility and scalability.

Industry 4.0 promises to unlock new levels of efficiency, innovation, and sustainability across sectors such as manufacturing, logistics, healthcare, and energy. In the era of rapid technological advancement and digital disruption, Industry 4.0 not only transforms production but also prompts a reimagining of industry itself. Organizations embarking on this transformative journey must embrace continuous adaptation and innovation to thrive in the digital age [9].

Need of AI, IOT, Machine Learning in Industry 4.0

In Industry 4.0, the integration of artificial intelligence (AI), Internet of Things (IoT), and machine learning (ML) technologies is crucial for several reasons like

Real-time Data Insights: IoT devices generate vast data in machinery, products, and production environments. AI and ML analyze this data for proactive decision-making, predictive maintenance, and process optimization.

Predictive Maintenance: AI and ML analyze IoT sensor data to predict equipment failures, scheduling maintenance efficiently, minimizing downtime, and extending asset lifespan [10-12].

Optimized Production Processes: AI-driven analytics identify inefficiencies and bottlenecks in production workflows, leveraging IoT data and ML algorithms to streamline operations, reduce waste, and enhance productivity.

In summary, the integration of AI, IoT, and ML in Industry 4.0 unlocks efficiency, productivity, and innovation across sectors. Harnessing data-driven insights and autonomous systems enables organizations to thrive in a competitive business landscape [13].

Changing technical requirement for Industry 4.0

The technical requirements for Industry 4.0 are rapidly evolving with the emergence of new technologies and the maturation of existing ones. Key evolving technical requirements include:

Interoperability: Industry 4.0 environments demand standardized communication protocols and interoperable platforms to facilitate seamless integration and data exchange between diverse components, machines, and systems [6-8].

Edge Computing: There's a shift towards edge computing solutions to process and analyze the growing volume of IoT-generated data closer to the source, reducing latency, conserving bandwidth, and enhancing real-time decision-making capabilities [7, 9].

Artificial Intelligence and Machine Learning: AI and ML technologies are pivotal in Industry 4.0 for predictive analytics, autonomous decision-making, and intelligent automation, requiring algorithms capable of extracting actionable insights, optimizing processes, and adapting to dynamic industrial environments [10,12].

Cyber security: With the proliferation of connected devices, robust cyber security measures such as encryption, authentication, access control, and intrusion detection are essential to safeguard sensitive data and critical infrastructure from cyber threats.

5G and Low-Latency Connectivity: Deployment of 5G networks and low-latency connectivity solutions is driving real-time applications, demanding reliable, high-speed communication networks to support bandwidth-intensive applications, remote monitoring, and seamless collaboration across distributed environments.

Digital Twins: Adoption of digital twin technology for virtual replicas of physical assets demands advanced modelling and simulation tools, data integration capabilities, and real-time synchronization between physical and virtual environments for simulation, optimization, and predictive maintenance.

Augmented Reality and Virtual Reality: AR and VR technologies are revolutionizing industrial interactions, requiring immersive interfaces, 3D visualization tools, and wearable devices to enhance situational awareness, training, and troubleshooting capabilities.

Sustainability and Green Technologies: Industry 4.0 emphasizes adopting green technologies and renewable energy sources, necessitating energy-efficient systems, eco-friendly materials, and innovative solutions to reduce carbon emissions and environmental impact.

In summary, the evolving technical requirements for Industry 4.0 underscore the digital transformation, innovation, and sustainability imperative in industrial settings. By embracing emerging technologies and addressing key challenges, organizations can leverage Industry 4.0 to enhance efficiency, agility, and competitiveness in the global market [9-11].

LITERATURE SURVEY

The emergence of Industry 4.0 has transformed manufacturing and industrial processes, with artificial intelligence (AI) and machine learning (ML) playing pivotal roles. This literature review aims to synthesize existing research on the impact of AI, ML and IoT within Industry 4.0, drawing insights from previous studies and identifying key trends and gaps in current knowledge.

Foundations of Industry 4.0:Previous research by Lu et al. (2017) laid the groundwork for understanding the core concepts of Industry 4.0, including cyber-physical systems and the Internet of Things (IoT) [14]. Their study emphasized the importance of digital technologies in enabling intelligent manufacturing ecosystems. Building upon this foundation, Schumacher et al. (2018) explored the integration of AI and ML techniques within Industry 4.0, highlighting their potential to drive efficiency, innovation, and competitiveness [15].

Applications of AI and ML in Manufacturing: Research by Tran et al. (2019) investigated the application of AI and ML in predictive maintenance for manufacturing equipment [16]. Their findings demonstrated significant improvements in equipment uptime and maintenance efficiency, illustrating the tangible benefits of AI-driven predictive analytics. Additionally, Wang et al. (2019) examined the role of AI-enabled robotics in automating production processes, showcasing how intelligent automation enhances productivity and flexibility in manufacturing operations [17].

AI and ML in Supply Chain Management:Studies by Jiang et al. (2018) and Sun et al. (2020) explored the application of AI and ML algorithms in supply chain management within the context of Industry 4.0. Jiang et al. (2018) investigated the use of predictive analytics for demand forecasting, highlighting the role of AI in improving supply chain visibility and responsiveness.

Sun et al. (2020) focused on AI-driven optimization techniques for inventory management, demonstrating how ML algorithms minimize stock outs and excess inventory while improving cost efficiency [18, 19].

Challenges and Ethical Considerations: Research by Mittal et al. (2019) examined the challenges and ethical considerations associated with the widespread adoption of AI and ML in Industry 4.0 [20]. Their study identified issues such as data privacy, algorithmic bias, and job displacement as significant concerns that require careful consideration. Additionally, Liu et al. (2021) emphasized the importance of robust cyber security measures to mitigate the risks of cyber threats and ensure the integrity of AI-driven industrial systems [21].

Future Directions and Opportunities: Looking ahead, research by Zhang et al. (2022) identified future research directions and opportunities for advancing the integration of AI and ML in Industry 4.0. Their study emphasized the need for interdisciplinary collaboration, regulatory frameworks, and ethical guidelines to harness the full potential of these technologies while addressing societal concerns. By synthesizing insights from previous studies, this literature review contributes to a deeper understanding of the transformative impact of AI and ML on Industry 4.0 and identifies avenues for further research and innovation [22].

NEP 2020 VISION

The National Education Policy (NEP) 2020 in the context of engineering envisions a transformative framework aimed at redefining there vamping the education system to align with the requirements of the 21st century. Here's an overview of the NEP 2020 vision for engineering education:

Holistic and Multidisciplinary Education: NEP 2020 emphasizes a holistic and multidisciplinary approach to engineering education, encouraging students to explore diverse fields of study beyond their core disciplines. This interdisciplinary approach aims to foster creativity, critical thinking, and problem-solving skills among engineering graduates, preparing them for the complex challenges of the modern world [23, 24].

Flexible Curriculum and Choice-Based Credit System (CBCS): The policy advocates for a flexible curriculum and the implementation of a Choice-Based Credit System (CBCS) in engineering education. This allows students to select courses based on their interests, aspirations, and career goals, enabling personalized learning experiences and fostering a culture of lifelong learning.

In essence, the NEP 2020 vision for engineering education aims to transform the traditional paradigm of engineering education into a dynamic, inclusive, and future-ready ecosystem that nurtures innovation, fosters excellence, and contributes to national development.

If we take Mechanical Engineering degree program me as a case study then inclusion of subjects of disciplines like computer Science, AI, ML, Data Sciences, Electronics & Communication like AI, SAP, Programming, IoT, Electronics, Communication Technology, etc. at various semester levels from 1st to 8th semester will create a multi faculty, knowledge driven, multi skilled mechanical engineering human resource catering to the needs of Industry 4.0 [25-26].

CONCLUSION

The knowledge of subjects and futuristic technologies like AI, ML and IoT, etc in the technical human resource an important requirement of Industry 4.0. So also the vision of NEP 2020 is to create a multi skilled, multi disciplinary, knowledge driven technical human resource for enhanced employability. Thus inclusion of futuristic technology based domain areas of subject knowledge across the engineering and diploma students of any branch will just not be in consonance with the vision of NEP 2020 but will also greatly cater to the emerging needs and requirements of Industry 4.0. Thus we can conclude that when the government is keen to implement NEP 2020, the rampant speed with which the institutions are gonging Autonomous, the societal demand of creation of employment, the advent of Industry 4.0, the skilled human resource requirement of industry 4.0, India emerging as hub for skilled human resource requirement of the world, it is high time for the Indian educational institutions and the universities to update, upgrade their curriculum with futuristic knowledge, in all the faculty domains for creating better employment opportunities for the youth, needs of the industries & the business world and support the country in becoming the 3rd strongest economy in the world.

REFERENCES

1. Aggour, K.S.; Gupta, V.K.; Ruscitto, D.; Ajdelsztajn, L.; Bian, X.; Brosnan, et al. Artificial Intelligence/ Machine Learning in Manufacturing and Inspection: A GE Perspective. Mach. Learn. Revol. Mater. Res. 2019, 44, 545–558.

2. Sodhro, A.H.; Pirbhulal, S.; de Albuquerque, V.H.C. Artificial Intelligence-Driven Mechanism for Edge Computing-Based Industrial Applications. IEEE Trans. Ind. Inf. 2019, 15, 4235–4243.

3. Lin, C.; Deng, D.; Kuo, C.; Chen, L. Concept Drift Detection and Adaption in Big Imbalance Industrial IoT Data Using an Ensemble Learning Method of Offline Classifiers. IEEE Access 2019, 7, 56198–56207.

4. Diez-Olivan, A.; Del Ser, J.; Galar, D.; Sierra, B. Data Fusion and Machine Learning for Industrial Prognosis: Trends and Perspectives Towards Industry 4.0. Inf. Fusion 2019, 50, 92–111.

5. Zheng, X.; Wang, M.; Ordieres-Meré, J. Comparison of Data Preprocessing Approaches for Applying Deep Learning to Human Activity Recognition in the Context of Industry 4.0. Sensors 2018, 18, 2146.

6. Ruppert, T.; Jasko, S.; Holczinger, T.; Abinyi, J. Enabling Technologies for Operator 4.0: A Survey. Appl. Sci. 2018, 8, 1650.

7. Wuest, T.; Weimer, D.; Irgens, C.; Thoben, K. Machine Learning in Manufacturing: Advantages, Challenges, and Applications. Prod. Manuf. Res. 2016, 4, 23–45.

8. Qi, Q.; Tao, F. Digital Twin and Big Data Towards Smart Manufacturing and Industry 4.0: 360 Degree Comparison. IEEE Access 2018, 6, 3585–3593.

9. Ge, Z.; Song, Z.; Ding, S.X.; Huang, B. Data Mining and Analytics in the Process Industry: The Role of Machine Learning. IEEE Access 2017, 5, 20590–20616.

10. Gupta S., Sharaff, A., Nagwani, N.K., "Frequent item-set mining and clustering based ranked biomedical text summarization" Journal of Supercomputing (2022) (SCIE, IMPACT FACTOR 2.5) https://doi.org/10.1007/s11227-022-04578-1

11. Gupta S., Sharaff, A., Nagwani, N.K., "Control stochastic selection based biomedical text summarization using Sim-TLBO" Arabian Journal for Science and Engineering 2022. (SCIE)

12. Gupta S., Sharaff, A., Nagwani, N.K., "Semantic Classification with Enhanced Topic Modeling on Biomedical Literature for Cancer Hallmark Analysis" Multimedia Tools and Applications 2023 (SCIE)

13. Alvi, S. (2021). National Education Policy 2020: A Game Changer in Indian Education System. Journal of Education and Learning, 10(1), 59-68.

14. Yang Lu. Industry 4.0: A survey on technologies, applications and open research issues Journal of Industrial Information Integration Volume 6, June 2017, Pages 1-10.

15. Andreas Schumacher, Tanja Nemeth, Wilfried Sihn. Road mapping towards industrial digitalization based on an Industry 4.0 maturity model for manufacturing enterprises July 2018 Procedia CIRP 79:409-414 DOI: 10.1016/j.procir.2019.02.110.

16. Trung Ngọc Tran et a. An overview of the application of machine learning in predictive maintenance. Petrovietnam Journal 10:47-61.2021.

17. Weiyu Wang ,Keng Siau Artificial Intelligence, Machine Learning, Automation, Robotics, Future of Work and Future of Humanity: A Review and Research Agenda. Journal of Database Management 30(1):61-79.2019

18. Bao Jiang, Jian Li, Siyi Shen, Supply Chain Risk Assessment and Control of Port Enterprises: Qingdao port as case study, The Asian Journal of Shipping and Logistics, Volume 34, Issue 3, 2018, Pages 198-208, ISSN 2092-5212,

19. Xu Sun, Hao Yu ,Wei Deng Solvang. Industry 4.0 and Sustainable Supply Chain Management January 2021 Lecture Notes in Electrical Engineering 737:595-604 DOI: 10.1007/978-981-33-6318-2_74

20. Ankesh Mittal, Pratima Verma, Vimal Kumar, Tugrul Daim, Nagendra Kumar Sharma, Identifying and prioritizing impediments of industry 4.0 to sustainable digital manufacturing: A mixed method approach, Journal of Cleaner Production,Volume 356,2022,131639,https://doi.org/10.1016/j.jclepro.2022.131639.

21. Y. Liu, Y. Li, Y. Wang, X. Zhang, H. B. Gooi and H. Xin, "Robust and Resilient Distributed Optimal Frequency Control for Microgrids Against Cyber Attacks," in IEEE Transactions on Industrial Informatics, vol. 18, no. 1, pp. 375-386, Jan. 2022, doi: 10.1109/TII.2021.3071753.

[22] Caiming Zhang, Yong Chen, Hong Chen, Dazhi Chong. Industry 4.0 and its Implementation: a Review.

Information Systems Frontiers. June 2021. DOI: 10.1007/s10796-021-10153-5

23. Gupta, R. (2020). National Education Policy 2020: A Roadmap for India's Future. International Journal of Applied Engineering Research, 15(24), 139-144.

24. Jena, P., & Panda, P. (2021). National Education Policy 2020: A Critical Analysis. International Journal of Engineering Research and Technology, 14(3), 630-633.

25. Aggarwal, A. (2021). National Education Policy 2020: A Review. International Journal of Scientific Research and Review, 10(1), 349-356.

26. Bajpai, R. (2021). National Education Policy 2020: A Paradigm Shift in Indian Education System. International Journal of Recent Technology and Engineering, 9(3), 4767-4771.

27. Dangi, K. (2021). National Education Policy 2020: A Game Changer in Indian Education System. International Journal of Research and Analytical Reviews, 8(1), 348-354.

28. T. Dhanabalan, A. Sathish. Transforming Indian Industries through Artificial Intelligence And Robotics In Industry 4.0. International Journal of Mechanical Engineering and Technology (IJMET) Volume 9, Issue 10, October 2018, pp. 835–845, Article ID: IJMET_09_10_087.

Potential of IoT in Higher Education

Sukhada Sandeep Dhatrak
Department of Industrial Electronics Engg
VPM's Polytechnic
Thane, Maharashtra
✉ Supriya17gupta@gmail.com

ABSTRACT

In the coming years, technology will impact the learning experience in many ways. By supporting IoT, educational institutions can enable more advanced learning and improve learning outcomes. The purpose of this research is to find the potential of IoT in higher realms. It takes effort to realize the full potential of IoT systems and technologies. This article presents research on the impact of IoT on higher education, specifically universities. IoT will dramatically change how universities operate and improve student learning .Brings great potential to universities and other educational institutions. The Internet of Things requires developments in which universities can play a pioneering role. Researchers and students are uniquely positioned to drive IoT discovery and development Furthermore , this paper provides evidence of this. The future of IoT in higher education in the coming years is a big challenge for higher education.

KEYWORDS *: Internet of things, Higher education, Aspect of IoT, Potential of IoT, Components of IoT.*

INTRODUCTION

The Internet of Things (IoT) is a transformative process in many aspects of our daily lives. Technologies differ from previous innovations because they are widespread and drive solutions. Advances in IoT are an important strategic technology trend . Ubiquitous sensors and the ability to bridge the gap between the physical world and the machine world. A major paradigm shift is the ability to integrate sensors into any object and use machine-to-machine (M2M) communication.

The Internet of Things is growing rapidly and is becoming an exciting and exciting topic. There are many signs that the Internet of Things will change the sector, including higher education institutions, especially universities. Become a pioneer in Internet of Things technology development with innovative and creative models.

IoT is a global physical network that connects devices, things and objects to the Internet. It is structures that communicate or interact with the internal and external environment as shown in Figure 1, the purpose is to exchange information through speech recognition devices. Therefore, IoT can be connected to anything and anyone from anywhere. The goal is to identify, track and manage assets. Online networks expand human-to-human (H2H) communication. Human-to-Thing (H2T) or Thing-to-Thing (T2T), as shown in Figure 2 .

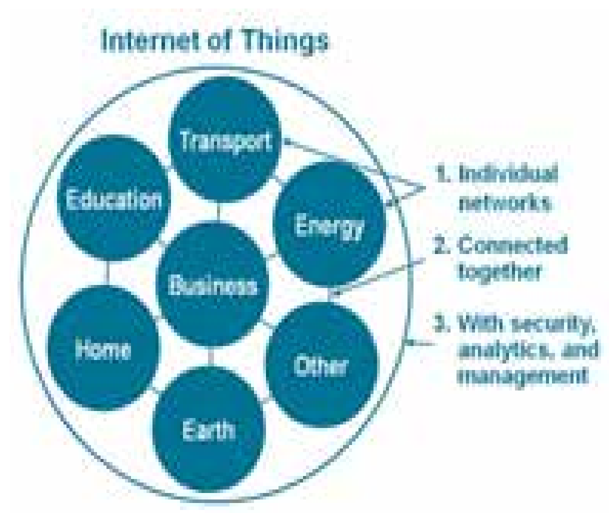


Fig. 1 IoT viewed as a global network
(Source: Cisco IBSG, April 2011)

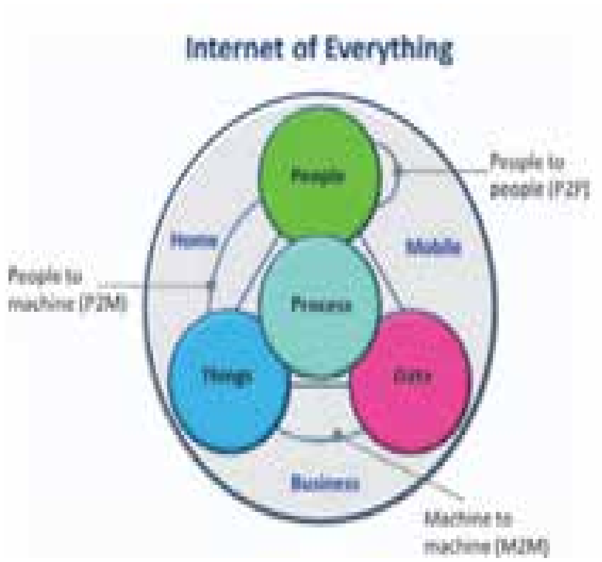


Fig.2. Internet of everything

(Source: Cisco, April 2011).

Many research institutions and analysts are predicting the future of IoT and its potential impact on the Internet. Billions of physical devices around the world are equipped with digital sensors and connected to each other using arbitrary networks. By 2023, 4 billion devices will be connected, more than the entire population on Earth at the time, and that number is expected to triple to 38. The ability to interact with many everyday objects connected to the Internet provides access to unlimited information anytime, anywhere.

The IoT vision is based on the belief that microelectronics are constantly evolving. Communication and information technology as we have come to know it in recent years will continue to exist for the foreseeable future. Applications of IoT are already being used in areas such as healthcare and customer service. Sometimes it's obvious how the Internet of Things will benefit education, but sometimes it's not so obvious. The biggest impact of connected devices is on higher education and its associated potential impacts.

The future of universities is not the use and application of new technologies. This article provides an overview of how IoT is impacting the future of higher education. Some aspects of IoT are relevant to the higher education sector.

BASIC COMPONENTS OF IOT

Fig 3: Technology convergence
(Source: Friess, 2013)

IoT is helping technology researchers to develop cheaper wireless devices. It is a system that requires less energy and can be integrated into all kinds of devices . The three IoT components that enable seamless connectivity are: Hardware: sensors,actuators and embedded communication devices, middleware: storage and computing tools for data analysis and presentation: new and easy-to-understand ideas and interpretations Tools are available on various platforms and can be designed for different purposes. Communicating with IoT nodes, from embedded technologies like ZigBee to low power with wireless technology and the power of bit-by-bit transmission, IoT will surpass other formats. Develops industrial and personal technology systems that enable microcomputer design for wireless data Communication. Some of these technologies may add some form of wireless sensor (WSN) capability.

CONCEPT OF DIGITAL CAMPUS

In the digital campus, technology can reduce operational costs, increase security and provide tools for students ,staff and researchers . Its benefits provide real value to university activities, operation and development ,student and researcher experience. Firstly it reuses the IT service delivery platform (end-to-end infrastructure) to provide network connectivity, mobility and security to all applications and services to all over the camp. Second, there are many Internet of Things (IoT) applications. It is managed through a platform system that supports academics and enables training and coaching. "To improve educational experience and improve performance": IoT applications differ from traditional methods. IoT Digital campus applications include five main areas: Building Control and Management; security and access control; video and information systems; location and attendance system;Energy Monitoring and Control system as shown in Figure 4:

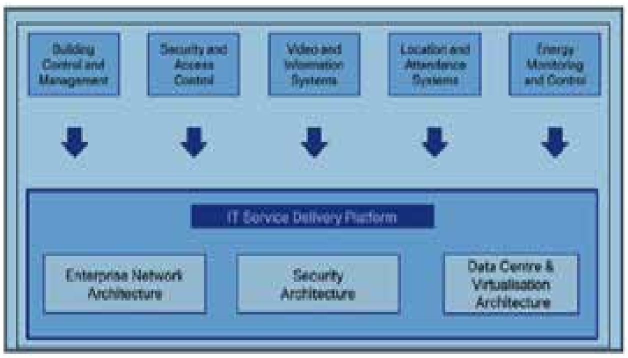


Fig. 4: IoT Applications for the Digital Campus (Source: Cisco- Digitizing Higher Education to enhance experiences and improve outcomes.)

Wireless networks play an important role in digital schools and must be designed accordingly. There is a huge need for new universities.

Additionally, IoT is reinventing and transforming teaching and learning on campus. For example, IoT adopts a similar perspective on education, and by distributing educational spaces, training centers, sports venues, dormitories, restaurants, and students on campus, students can access the campus anytime and anywhere through the Internet of Things. You can go to physical, mental, and skill-based places where you can pick up a whole range of learning and training. This will lead to universities becoming ubiquitous learning and training .

IMPACT OF INTERNET OF THINGS ON HIGHER EDUCATION

Higher education institutions in general, and universities in particular, can collaborate across disciplines to advance advances in IoT technologies, business models, and ethics, and drive future IoT-enabled economies. We can also collaborate with business schools to define and design his IoT courses to develop new business models. According to Zebra Technologies, higher education institutions will begin to develop and use solutions such as radio frequency identification (RFID) and cloud computing using his IoT technology, allowing them to analyze and manage big data.

The Internet of Things is not only renewing technology and developing the industry, but it is also leading the industrial development. Extending the changes to the wider community, including higher education institutions. Leading change and innovation in higher education. The Internet of Things will cause changes in educational technology, changes in education, changes in teaching, and changes in functional observations of student performance. These days, especially university students, E-learning applications allow students to learn at their own pace and relearn. Classroom and home experiences increase progress and satisfaction. Teachers can provide individual training and continuous assessment of students . IoT technology allows teachers to collect data on student performance and make informed decisions. This data analysis helps educators make the right changes. Connected tools allow educators to intervene and to keep attendance records simplified. It offers warm-ups and exercises that students can do on their own equipment. Educators can monitor students' mental performance during class. Addition, these tools can divert the student's attention.

This knowledge enables organizations to make informed decisions to enhance knowledge and experience of student learning, administrative skills, and campus safety. According to Zebra Technologies (2015), by improving asset knowledge, educational institutions can improve operational efficiency and a safer campus design.

Likewise, outside the classroom, universities can use connected devices to conduct assessments and monitor students, staff, resources and assets and reduce operating cost. Mobile technology and IoT can help universities improve campus safety and enhance access to information and applications at any time from anywhere. IoT is transforming not only facility management but also the learning experience for students by connecting people, data, and things.

FUTURE OF IOT IN HIGHER EDUCATION

Universities have long recognized that technology can disrupt teaching, learning and assessment. Furthermore, technological change is essential. If the modern university is to differentiate its students' access to high-quality educational programs and content then they must have the ability to train students to use new technology effectively. With the development of IoT, many universities have benefited from it. The Internet is firmly entrenched in universities, and e-learning is common in most university systems, as well as IoT enables better operational efficiency and learning environments. IoT can support classroom teaching by improving the learning environment. It also improves teaching resources, improves teaching methods and techniques, increases administrative efficiency and saves administrative costs. Learning resources on devices such as e-books however, there is a need for new teaching technologies. Technology enhances the learning experience in many ways. The learning experience continues to become more virtual, students will consume knowledge and learn in new ways and classrooms. In the end, learning is an amazing experience. Teachers and students accelerate knowledge while providing new ideas and solutions. It also prepares students for their future careers and workplaces.

Technology will always have a place in all education sectors. Opportunities to study science, technology, engineering and mathematics (STEM) courses, e.g. IoT technology. It's easy to imagine how IoT capabilities could be used in STEM fields, robotics, and anything that involves collecting specific data. And all of this within the potential of the Internet of Things. Ultimately, however, educators must be able to identify the right technology and properly integrate it into the classroom for successful learning. While the core technologies of IoT are not yet clear, the point is certainly that much of the content is a result of 's new development phase. Given the need for advanced study, choosing the Internet of Things major is relatively easy and applies to graduate students. However, undergraduate students still require a wide range of core courses, so it is not easy to choose an IoT major on your own like other majors . New teaching methods for undergraduate students need to be explored . Different universities should consider the appropriate approach according to their specific characteristics. The system approach and course content must be gradually established and improved. As IoT achieves unity between the virtual world and the physical world, many new learning methods and cross-sectional areas will emerge in the future .

Additionally, the future IoT economy can be shaped by experts and leaders in higher education. Therefore, the field of higher education must work together,Companies and industries to shape and build the future of the IoT-enabled economy. The higher education sector, particularly universities, has the potential to drive the future of IoT course design Technologies for technical and business leaders and student support and researchers are working in a variety of ways to develop new business methods that utilize IoT technologies.

CHALLENGES OF IOT IN HIGHER EDUCATION

The Internet of Things brings a lot of challenges and opportunities to higher education. The unique growth of ubiquitous computing, the development of his IoT technologies such as cloud computing, big data, and analytics not only improve the core values of education and the quality of research, but also contribute to the development and promotion of education. will also contribute. New digital culture of IoT society. With an increase in online degree options and seamless access to course content in structured and unstructured formats, IoT is introducing digital dynamics to higher education institutions. The IoT represents a dramatic shift in traditional educational paradigms, while integrating a broader range of disciplines, including the social sciences, to enhance the value of big data available on social media. Some of his IoT challenges in higher education include:

Cloud Computing

Many universities are using hybrid cloud as their enterprise architecture to host IoT applications. Millennials, the most tech-savvy students in college, and the rise of tablet and mobile technology have opened new ways to increase the effectiveness of enterprise architecture, educational technology, and research and learning environments. With ubiquitous computing, the cloud provides seamless connectivity and services for information technology services. Currently, many higher education institutions' enterprise architectures rely on hybrid cloud infrastructures with private cloud computing platforms, but enterprise and educational applications are gradually moving to the public cloud. The demand for content in educational technology, the significant increase in audio and video content for education, and the need for active enterprise networks require that the enterprise architectures of these institutions reduce latency.

Instructional Technologies

The use of LMS learning management systems such as Moodle and Blackboard is increasing and creating large amounts of structured and unstructured data, including audio and video. It gives an opportunity for students to access educational programs on demand at any time .

Mobility Applications

IoT applications can integrate mobile learning applications. The ideal application helps students improve their learning effectiveness. Some of these applications are also used by teachers to teach highly specialized concepts, complex physics, scientific simulations, and social topics.

Security and Privacy

Deploying IoT technology brings new and unique security and privacy challenges. Ensuring the security of IoT devices and services requires addressing these challenges and issues. One of the fundamental criteria of IoT is reliable privacy and security mechanisms . Higher education is vulnerable to security. The industry needs to develop standards to secure IoT applications. Because higher education creates millions of people. Applications must morally and ethically engage the future workforce to address cybersecurity issues. Society is becoming increasingly dependent on IoT applications. Therefore, developing effective and appropriate solutions to address IoT security challenges requires a collaborative approach to security and protection. Additionally, realizing the full potential of IoT requires strategies that consider people's privacy. Therefore, to take advantage of these opportunities, new strategies must be developed that take into account.

Research Computing

Higher education will continue to benefit from the introduction of the IoT. Using big data, small universities can increase the breadth of interdisciplinary research and put in high performance computing (HPC), big data platforms and analytics. The need to define cooperation with the IoT ecosystem that uses mobile technology. Technical laboratories use audio and video, UAV, Raspberry Pi and open source systems for improving the learning process in engineering programs. A lot of big data generated by social media and general computing is still being used. through distributed computing platforms such as HPC, GPU clusters, Hadoop clusters and big data analytics to improve IoT research.

Quality and Ethics

The quality of learning both online and on campus and the rising cost of higher education has been intensely debated in latest years. The IoT offers unique opportunities to deliver digital courses. However, it also introduces challenges to maintain the quality of instruction and evaluation of students' work. IoT educational applications need tools and technologies for instructors, professors and the scientific community to improve the quality of research and address ethics issues within higher education.

Financing

The cost of information technology increases over the years depending on content and application. In addition to information technology IoT infrastructures operating costs, information technology infrastructure and services cost is increasing. Higher education needs to develop new ideas for funding information technology infrastructure and services.

FUTURE WORK

Technological advances such as the Internet of Things will help universities solve many challenges. IoT systems have great potential to create greater value.

CONCLUSION

The aim of this research is to examine the potential of IoT in higher education and find ways to increase it. You can reap the benefits of solving the problem and reduce the problems associated with it. The project focuses on the implementation of IoT in higher education.

REFERENCES

1. Agarwal, S. and S. Pati, Study of Internet of Things. International Journal for Scientific Research & Development, 2016.
2. High, P.G., High, P. (2015). Gartner: Top 10 Strategic Technology Trends For 2016. http://www.forbes.com/sites/peterhigh/2015/10/06/gartner-top-10-strategic-technologytrends-for-2016. 2015.
3. Ning, H. and S. Hu, Technology classification, industry, and education for Future Internet of Things. International Journal of Communication Systems, 2012.
4. Friess, P., Internet of things: converging technologies for smart environments and integrated ecosystems. 2013: River Publishers.
5. Chen, S., et al., A vision of IoT: Applications, challenges, and opportunities with china perspective. IEEE Internet of Things journal, 2014.
6. Kahlert, M., Understanding customer acceptance of Internet of Things services in retailing: an empirical study about the moderating effect of degree of technological autonomy and shopping motivations. 2016, University of Twente.
7. Jin, D., Application of" Internet of Things" in Electronic Commerce. International Journal of Digital Content Technology & its Applications, 2012.
8. Porter, A. and Mark Sherwin, The Digital Campus The Online Future For Higher Education.2013.
9. Tianbo, Z. The internet of things promoting higher education revolution. in Multimedia Information Networking and Security (MINES), 2012 Fourth International Conference on 2012. IEEE.
10. Ghazal, S., Z. Samsudin, and H. Aldowah, Students' Perception of Synchronous Courses using Skype-based Video Conferencing. Indian Journal of Science and Technology, 2015. 8(30).
11. Kortuem, G., et al., Educating the Internet-of-Things generation. Computer, 2013. 46(2):.
12. Hanan Aldowah1, 3, Shafiq Ul Rehman2, Samar Ghazal1, 3, Irfan Naufal Umar 1, Internet of Things in Higher Education: A Study on Future Learning. Hanan Aldowah et al 2017 J. Phys.: Conf. Ser. 892 012017
13. Mineraud, J., et al., A gap analysis of Internet-of-Things platforms. Computer Communications,2016.

AI Supported Robotic Process Automation

Kirti Agashe
ksagashe@vpmthane.org

Pradnya Bodke*
pradnyabpdke886@gmail.com

Department of Industrial Electronics
VPM's Polytechnic
Thane, Maharashtra

ABSTRACT

Robotic Process Automation (RPA) is getting significant attention among the recently emerging technologies. Software robots act just like humans in understanding the sensor actions, responding to the keystrokes, directing systems, identifying and extracting data, and performing a variety of intellectual tasks. Robots are getting developed with three leading open-source RPAs such as UiPath Studio, Automation Anywhere and Blue Prism to interact with the real world. Such RPAs are also available with AI integration. Robotic processes can be made more sophisticated by integrating AI into them. This paper will focus on a comparative study of these platforms that will help commercial and experimenting individuals to choose the right platform for applications. A supporting case study demonstration of UiPath and UiPath AI Center is discussed which has considered both the front and back offices.

KEYWORDS *: Robotic process Automation, UiPath, Automation anywhere, Blue prism, AI.*

INTRODUCTION

Process Automation encompasses both Hard Automation, which involves specific and repetitive tasks performed by machines or robots, and Soft Automation, a more flexible version allowing for customized programming to meet product requirements [1]. Robotic Process Automation (RPA) falls under Soft Automation, enabling the automation of various manual processes typically burdening human workers with repetitive tasks [2].

In RPA, software bots are programmed to execute workflows, including tasks such as data reading and writing, numeric calculations, data modification, and updates [2]. Popular RPA tools include UiPath Studio, Automation Anywhere, Blue Prism, and others [3]. The rapid advancement of AI technology is driving the demand for faster and more efficient automation solutions. AI holds the potential to revolutionize business operations, increase efficiency, and enhance consumer satisfaction [4].

McKinsey reports that integrating generative AI with other technologies and automation could boost productivity by 0.2 to 3.3 percentage points annually [4].According to the findings of the Bain research study, improvement in productivity and efficiency is (85%), followed by cost savings (35%)are the most common motivations for adoption of AI [5]. As shown in the graph (Fig 1) few business sectors are implementing AI supported automation earlier and faster. The chart shows the percentage of adoption.

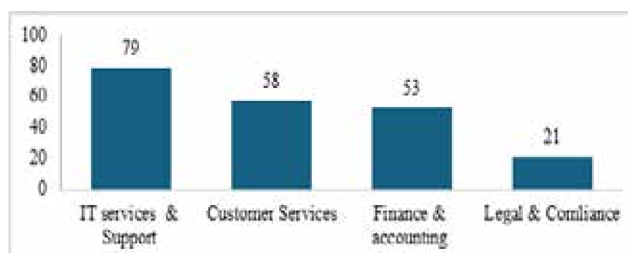


Fig 1. Adoption of AI in automation as per Bain research study

According to the Bain research study,70% of respondents believe that AI-driven automation is extremely significant and vital. 45% believe that the melding of AI and automation will lead to a significant transformation with unique opportunities.[5] The chart in Fig 2 shows the percentage of novel opportunities possible with AI adaption.

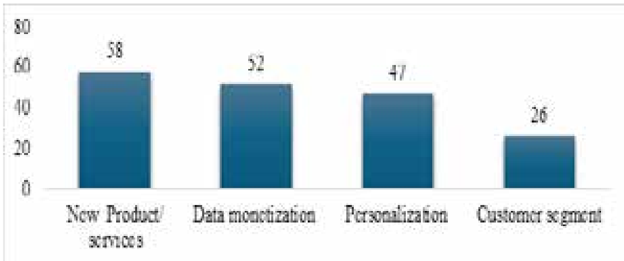


Fig 2. Opportunities developed with the Adoption of AI in different sectors as per the Bain research study.

SYSTEM OVERVIEW

According to the Gartner study in 2023, Fig 3 shows the magic quadrant report that includes 16 enterprise RPAs.[6]

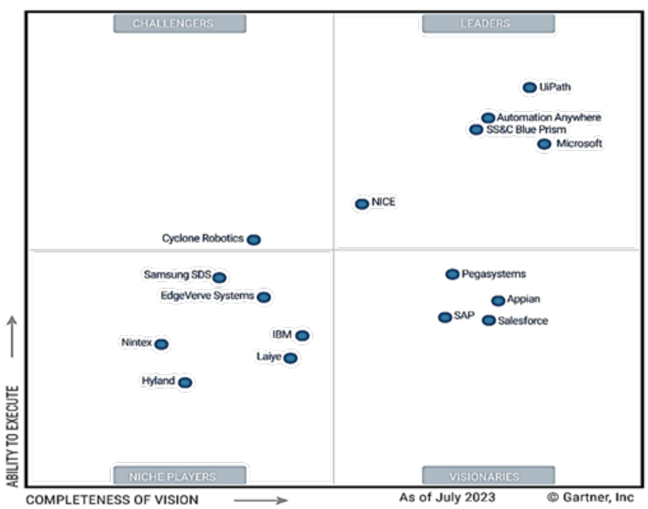


Fig 3 Magic quadrant for Robotics Process Automations

According to this report UiPath, Automation Anywhere, and SS&C Blue Prism are observed to be the best-leading RPAs and UiPath is recognized as a leader in the RPA. In this paper we are comparing these three promising RPAs .

Blue Prism

Blue Prism was developed by a group of process automation experts in 2001 to improve the efficiency and effectiveness of organizations needed for automation. [7] It provides a digital workforce designed to automate complex, end-to-end operational activities. [8] It has a large library of automation. It is used in analytics and decision management applications. It is a secure and stable product.

UiPath

UiPath, established in 2005, is a leading open-source platform for Robotic Process Automation (RPA) [2]. Serving as an orchestrator architecture, UiPath facilitates the training and coordination of software robots. Its intuitive interface employs drag-and-drop functionality to construct workflows or sequences, available in classic and modern experiences. UiPath features two robot types: attended (requiring human assistance) and unattended (operating autonomously) [2].

Automation Anywhere

Automation Anywhere, Inc., formerly known as Tethys Solutions, LLC, introduced a fully web-based, cloud-native workspace in 2010, offering unparalleled automation flexibility [9]. Available in Server edition, this workspace enables users to develop automation processes with centralized security, user management, collaboration, deployment, and backup features. Being SaaS-based, it boasts rapid implementation and seamless pluggability. With API integration, Automation Anywhere workspace primarily serves business purposes.

COMPARATIVE STUDY

We have compared the top 3 RPA Tools . The comparison is based on the parameters as shown in Table 1.

Basic parameters suggest architecture type, and whether supported by attended or unattended automation. Script and visual designer is for the graphic user interface. The openness of the platform states whether documentation is available or not. Recorder helps in faster coding and design implementation. Programming skills indicate user training. Community addition allows open sourcing. Future scope states how useful a particular technology can be in near future. From this comparison, UiPath is observed to be the best RPA tool as on today and we have used the same for the case study.[10]

Table 1. Comparison of three RPAs

Parameters	UiPath	Automation Anywhere	Blue Prism
Architecture Type	Web-Based Orchestrator	Client- Server Based	Client- Server Based

Front Office/ Attended Automation	Available	Not Available	Available
Back Office/ Unattended Automation	Available	Available	Available
Script Based Designer	Not Available	Not Available	Available
Visual Process Designer	User friendly	Moderate	Developer friendly
Openness	Free Forums and documentation available	Commercial documentation available	Commercial documentation available
Recorder	Available	Not Available	Available
Control through Coding	Not Available	Available	Available
Future Scope	Indefinite	Comparatively Less	Comparatively Less
Community Eddition	Available	Not Available	Available

UIPATH AI CENTER

It is a cloud-based architecture where we can integrate automation with AI and Machine Learning ML models.

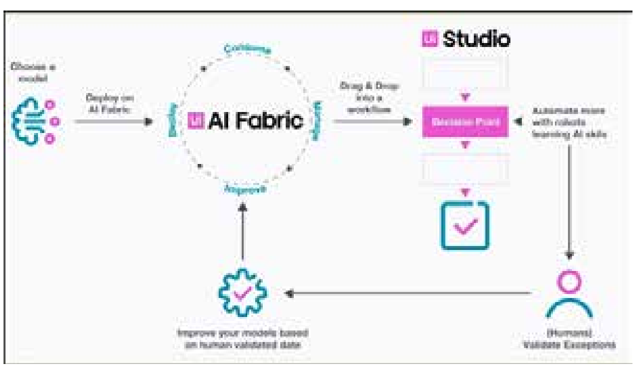


Fig 4 UiPath AI Center Architecture

IMPLEMENTATION

Here we have done an image analysis using UiPath studio and AI center. UiPath AI center has in-built Machine Learning packages and Skills. These ML packages and skills can be utilized as per user needs. User need to select ML package and configure it. Later ML skill and model is deployed. Sequence is created with UiPath Studio Application and input is fed before executing the operation. Fig 4 and 5 show the steps. Fig 6 shows the input given to the UiPath studio in the form of image and program is executed to count the number of coffee glasses in the sample image. The glasses are marked in Fig7 by UiPath studio. Image analysis was done by a robot and it took only 27 to 29 seconds to analyse the image and produce the correct output.

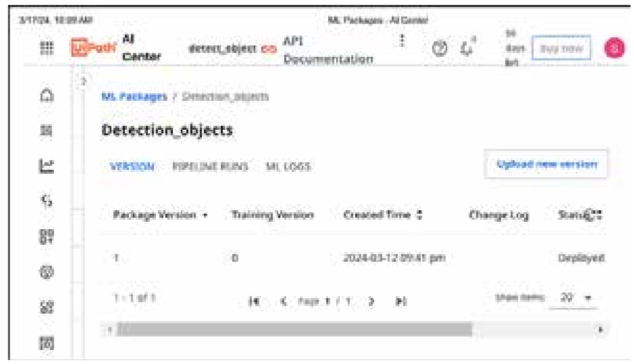


Fig 4 UiPath AI Center View

Fig.5 Sequence from UiPath

Fig 6 Input to the UiPath Studio

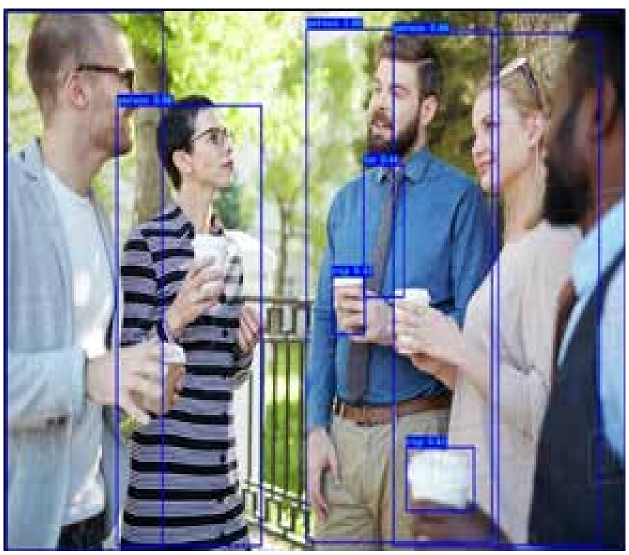


Fig 7 Output from the UiPath Studio

FUTURE SCOPE

In the future with AI and ML integration, the scope of UiPath will extend to the point where Bots will perform simple operations without human intervention. We can extend the implementation of UiPath and UiPath AI center to automate the surveillance system where we can keep records of people visiting the places and classify the visitors as Regular and new which can be accessed later by the authorized person.

CONCLUSION

Robotic Process Automation (RPA) is providing fast solutions for the tedious jobs of data identification, extraction and analysis with no human intervention. UiPath Studio is a user friendly platform to interact with the real world problems. Robotic processes can be made more sophisticated by integrating AI supported by this tool. A supporting case study demonstration of UiPath and UiPath AI Centre has assured the effectiveness of the concept of AI supported RPA for the efficient automation.

REFERENCES

1. UIPath vs Automation Anywhere-Blue Prism, UiPath Community Forum - Robotic Process Automation, 2017.[online].
2. Lacity, M. (2018). Robotic Process Automation: The Next Transformation Lever for Shared Services. Curators' Professor. College of Business University of Missouri-St. Louis.
3. Jalonen, H. (2018). Assessing Robotic Process Automation Potential. Master of Science. Tampere University of Technology.
4. https://start.uipath.com/rs/995-XLT-886/images/UiPath-Automation-and-AI-Trends-2024.pdf?version=0
5. https://www.uipath.com/assets/downloads/uipath-bain-ai-and-automation-report
6. https://www.uipath.com/resources/automation-analyst-reports/gartner-magic-quadrant-robotic-process-automation
7. Blue Prism. (2017). What we do - Blue Prism. [online]Available at: https://www.blueprism.com/about[Accessed 15 March 2024]
8. "Robotic Process Automation from Blue Prism". Analyse. 1 May 2018
9. Automationanywhere.com.(2017). Automation Anywhere [online]. Available at: https://www.automationanywhere.com/
10. 978-1-5386-3785-2/18/$31.00 ©2018 IEEE/ 2018 Second International Conference on Advances in Electronics, Computer, and Communications (ICAECC-2018) Delineated Analysis of Robotic Process Automation tools.

Accuracy Enhancement of Algorithm Design for MIMO-OFDM System

Gauri Joshi*
✉ gauri.joshi@vpmmpcoe.org

Aparna Murkar
✉ aparna.murkar@vpmmpcoe.org

Gajanan Khapre
✉ gajanan.khapare@vpmmpcoe.org

Priyanka Nikam
✉ priyanka.nikam@vpmmpcoe.org

Department of Electronics and Telecommunication Engineering
VPM's MPCOE
Velneshwar, Maharashtra

ABSTRACT

This paper focuses on enhancing the accuracy of Algorithm Design for MIMO-OFDM systems, aiming to mitigate the detrimental effects of pilot contamination. It introduces a Bayesian Channel Assessment technique and advocates for algorithm construction using Singular Value Decomposition (SVD) and Space-Time-Block-Coding (STBC) methodologies. By leveraging STBC, the system achieves full diversity and diversity gain at high transmit rates, while implementing ISI-free SVD for channel coefficient matrix estimation. Comparatively, UW-OFDM systems demonstrate higher data throughput than CP-OFDM systems due to the incorporation of the Unique-Word (UW) strategy, where the guard interval is part of the DFT interval. Furthermore, the paper examines UW performance across various constellation approaches, including QPSK, 4-QAM, 8-QAM, and 16-QAM.

KEYWORDS *: MIMO-OFDM system, Bayesian channel recognition, STBC technique, SVD subspace method, Unique-Word*

NOMENCLATURES

{.}T	Transpose Operation
{.}H	Conjugate Transpose
IK	K×K Identity matrix
X⊗Y	Kronecker product of X and Y
vec(X)	Vector form of X

INTRODUCTION

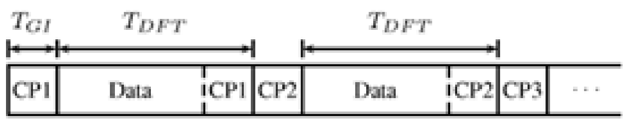
In the realm of contemporary wireless communication, MIMO systems stand as pillars, leveraging multiple antennas at both transmitter and receiver ends to optimize spectral efficiency and achieve high data rates. Space-time coding techniques bolster reliability by combating fading effects, while OFDM systems serve as bedrock, offering robustness, spectral efficiency, and adept handling of interference challenges. The integration of MIMO and OFDM, known as MIMO-OFDM, capitalizes on these strengths and seamlessly adapts to multi-user communication scenarios. Addressing pilot contamination issues, recent advancements have seen the introduction of compressive sensing methods, reducing overhead through improved channel estimation accuracy. Bayesian channel estimation techniques, like LS and LMMSE estimators, provide nuanced trade-offs between simplicity and precision. Meanwhile, Space-Time Block Coding (STBC) enriches multi-antenna communication by leveraging channel diversity for enhanced transmission parameter estimation. Moreover, the adoption of Unique Word (UW)-OFDM configurations offers a promising avenue to bolster throughput and spectral efficiency, presenting a viable alternative to conventional cyclic prefix methods [1-6].

REVIEW OF UW-OFDM: SYSTEM MODEL AND UNIQUE WORD GENERATION

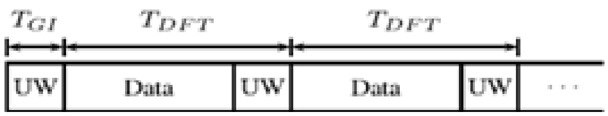
OFDM System Model

In OFDM systems, N data symbols are transmitted concurrently across N orthogonal subcarriers, allowing for efficient bandwidth utilization. By dividing a high-rate data stream into N lower-rate streams, OFDM minimizes the bandwidth required for transmission. The orthogonal nature of the system ensures that individual sub-streams remain orthogonal to each other, facilitating the mitigation of Inter-Symbol Interference (ISI).

UW-OFDM Symbol Generation



(a)



(b)

Figure-1: Transmit data structure for (a) CP-OFDM symbol and (b) UW-OFDM symbol

Figure 1 illustrates the structural disparities between conventional CP-OFDM and UW-OFDM transmit symbols. Key distinctions include: 1) The CP extends beyond the DFT window, whereas the UW remains within it. 2) CP varies randomly with each transmit data symbol, while UW remains consistent across symbols due to its deterministic nature. 3) CP is generated differently for each OFDM data symbol, while UW remains constant.

Let's discuss about the mathematical formulation of CP and UW symbols. First we consider CP-OFDM system, the QAM/QPSK modulated complex data symbol vector $\ddot{d} \in \mathbb{C}^{N_d \times 1}$ is called in frequency domain. In OFDM symbol at the DC position and at the band edges zero subcarriers are inserted. Thus frequency domain OFDM symbol $\ddot{x} \in \mathbb{C}^{N \times 1}$ can be written as:

$$\ddot{x} = B\ddot{d} \tag{1}$$

Where, $B \in \mathbb{C}^{N \times N_d}$ comprise unit row vectors at the position of data subcarriers and zero row vectors at the position of zero subcarriers. The DFT/FFT window length is shown by N. Now the time domain symbol $x \in \mathbb{C}^{N \times 1}$ is given as follows

$$x = F_N^{-1}\ddot{x} \tag{2}$$

Where F_N^{-1} is N-point DFT/FFT matrix and given by - $[F_N]_{k,l} = e^{\frac{-j2\pi kl}{N}}$. Now for any OFDM system the procedure discussed above is applicable. As we know UW is a deterministic sequence generated and is represented as $x_u \in \mathbb{C}^{N_u \times 1}$. And at the end of each time domain OFDM symbol this deterministic UW sequence is inserted. Formulation of this can be:

$$x = [x_d^T x_u^T]^T \tag{3}$$

Where $x_d \in \mathbb{C}^{(N-N_u)\times 1}$ represents a vector which has the random time domain samples that are affected by the data $\ddot{d}$. The two-step approach is helpful to generate UW-OFDM symbol.

Step-1: A time domain OFDM symbol having a zero UW is generated such that

$$x = [x_d^T\ 0^T]^T \tag{4}$$

Here we can obtain x from following equation

$$x = F_N^{-1}\ddot{x} \tag{5}$$

Step-2: By adding UW sequence x_u to the vector x we can get final desired UW-OFDM in time domain symbol as:

$$x' = x + [0^T\ x_u^T]^T \tag{6}$$

Now this OFDM symbol having UW is now passed over the wireless channel. At the receiver side subtracting the influence of inserted UW we can get re-sorted received vector.

Channel estimation part

Channel Model

We examine a wireless transmission system with M transmit and L receive antennas in this study. The channel the signal travels through is an AWGN channel with Rayleigh fading, and the channel coefficient matrix is the L×M complex matrix H. We needed to accurately estimate the channel in order to obtain the expected output at the receiver.

So many techniques are available for channel estimation. From those techniques we are using STBC based Bayesian channel estimation technique. Also SVD is used to estimate channel. The main goal of STBC is to get benefit of channel diversity. It can be achieved through encoding data streams into few structured blocks.

Recognition of STBC

At the receiver side we receive column vector Y, which is also known as measurement vector. In order to get the STBC candidates of transmitted signal, ML method is used. Now the recognized STBC $\hat{C}$ is used in order to maximize the Log-Likelihood function given below,

$$\hat{C} = \arg\max_{C\in\theta} \log(\Lambda[Y|C, X]) \tag{7}$$

Where log $(\Lambda[Y|C, X])$ is a log- likelihood function of Y which is conditioned on STBC $\hat{C}$ and communication parameter X.

Let's Consider that $N_b = (N/l)$ is the total no. of received blocks $\ddot{y}_v$. Thus the log-likelihood function can be expressed as bellow,

$$\log(\Lambda[Y|C, X]) = \sum_{v=1}^{N_b} \log(\Lambda[\ddot{y}_v|C, X]) \tag{8}$$

Space Time Block Code (STBC) [13], [20] maps a data vectors $\vec{x}$ into M×K (K>=M) code matrix C with n symbol entries. Each of K columns of C is given as

$$A_k \vec{x}_R + jB_k\vec{x}_I = \underbrace{[A_k\, jB_k]}_{\triangleq C_k} \underbrace{\begin{bmatrix} \vec{x}_R \\ \vec{x}_I \end{bmatrix}}_{\triangleq \vec{x}} \tag{9}$$

Where $\vec{x}_R$ is real part and $\vec{x}_I$ is imaginary part of transmitted symbol vector $\vec{x}$. However, A_k and B_k includes set of fixed M × n complex valued modulation matrices known to both the transmitter and receiver sides. The received data is corrupted by additive white Gaussian noise (AWGN) thus the overall received signal can be written as

$$\vec{y} = \begin{bmatrix} HC_1 \\ HC_2 \\ \vdots \\ HC_K \end{bmatrix} \vec{x} + \vec{\omega} = (I_K \otimes H) \underbrace{\begin{bmatrix} C_1 \\ C_2 \\ \vdots \\ C_K \end{bmatrix}}_{\triangleq C} \vec{x} + \vec{\omega} \tag{10}$$

Where $\vec{\omega}$ denotes White noise vector. Let channel remain constant over l received symbol vectors $\vec{y}$ having K code-word. From (10) we can write receive matrix as follows

$$Y = (I_K \otimes H)\, C\, X + W \tag{11}$$

Where $Y \triangleq [\vec{y_1}\ \vec{y_2} \cdots \vec{y_l}]$ channel output data symbol matrix and $X \triangleq [\vec{x_1}\ \vec{x_2} \dots \vec{x_l}]$ is input data symbol matrix. Also $W = [\vec{\omega_1}\ \vec{\omega_2} \dots \vec{\omega_l}]$ is white noise vector.

Alamouti Code Design

In STBC redundancy measurement through space time correlation and automatic classification is performed. This classification is done using Alamouti encoding technique [14]. Consider Alamouti code which is designed for (2x2) matrix. We form matrices as follows:

$$A_1 = B_1 = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}, \quad A_2 = -B_2 = \begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix} \tag{12}$$

Now we stack the received signals from two epochs assuming channel H is constant.

Thus we get

$$Y = \begin{bmatrix} H(A_1\vec{x}_R + jB_1\vec{x_I}) \\ H(A_2\vec{x}_R + jB_2\vec{x_I}) \end{bmatrix} + \text{noise} \tag{13}$$

After the estimation of unknown parameter H we get H ̂. Several techniques are used to estimate channel in that we proposed Subspace channel estimation method is in detailed described in [15]. Here we do not consider the noise added to system while estimating channel.

First we extract basis NL for left null space of Y without any noise consideration. Exciting data matrix (i.e. X with full row rank), Thus we get

$$N_L^H(I_K \otimes H)\, C\, X \leftrightarrow N_L^H(I_K \otimes H)C = 0 \tag{14}$$

The solution of this linear equation gives H estimate. Blind algorithm we consider here is same as proposed in ref. paper [15]. Let's recall blind equation and express it in vector form

$$C^T \otimes N_L^H.\mathrm{vec}(I_K \otimes H) = \vec{0} \tag{15}$$

After simple manipulation we can get expression as

$$\overbrace{\sum_{k=1}^{K} C_k^T \otimes (N_L^H\, E_k)}^{\triangleq \Psi}\ \overbrace{\mathrm{vec}(H)}^{\triangleq \bar{H}} = \vec{0} \tag{16}$$

Finally to get an estimate of $\bar{H}$, the channel vector H is obtained by Singular Value Decomposition (SVD) of Ψ in (16). The singular vector at right side of SVD equation which is corresponds to the least singular value of Ψ is collinear to $\bar{H}$.

EXPERIMENTATION AND RESULTS

In this paper we have designed OFDM system with 20MHz bandwidth, 5.6MHz sampling frequency. The AWGN Rayleigh flat fading channel is used. We used convolution encoder with the industry standard rate half (1/2), constraint length 7 code with (133,171) generator polynomial. Total 100 frames are transmitted. SNR loop chosen is 0 to 40 dB. A soft decision Viterbi algorithm is applied for decoding purpose.

Channel Estimation

We proposed STBC and SVD based channel estimation method, shown in Figure-2. First we implemented previous Bayesian channel estimation method based on CS scenario as described in [1] (method-1). Then we compare it with our investigated approach mentioned in section III (method-2) and plotted BER graphs. In method-1 Frame size used is 96 and FFT size used is 64 but we have extended it to 128 in method-2. Accordingly few parameters are changed and some of them are listed in Table 1.

Table 1. Comparison of PHY parameters used in method-1 and method 2

Parameters	Method-1	Method-2
Channel Bandwidth	20MHz	20MHz
Frame size	96	128
Coding rate	½	½
FFT length	64	128
Occupied subcarriers	52	68
Data subcarriers	48	64
No. of Pilots	4	4
Redundant subcarriers	16	16
Modulation Mode	4-QAM, 8-QAM, 16-QAM, QPSK	4-QAM, 8-QAM, 16-QAM, QPSK
OFDMSymbol duration	3.2 µs	4 µs

As frame size increased we need to increase FFT length up to 128. We can extend it up to 512 FFT length.

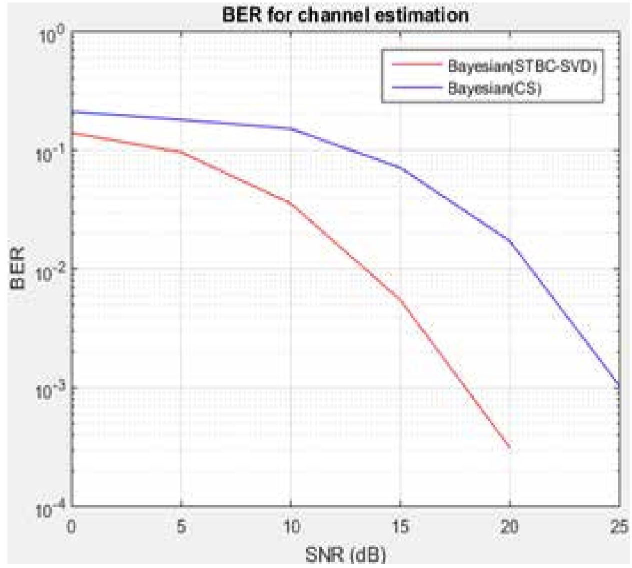


Figure-2: Compare BER of Bayesian channel estimation based on method-1(CS) and method-2 (STBC-SVD).

BER Comparison

We can see BER performance of UW-OFDM system is evaluated against CP-OFDM system in Figure-3 and the theoretical values are listed in Table 2. BER is a function of SNR 0 to 40 dB. BER for UW varies from 0-10-4 while BER for CP varies from 0-10-3. This result shows BER of UW is degraded as compare to conventional CP approach.

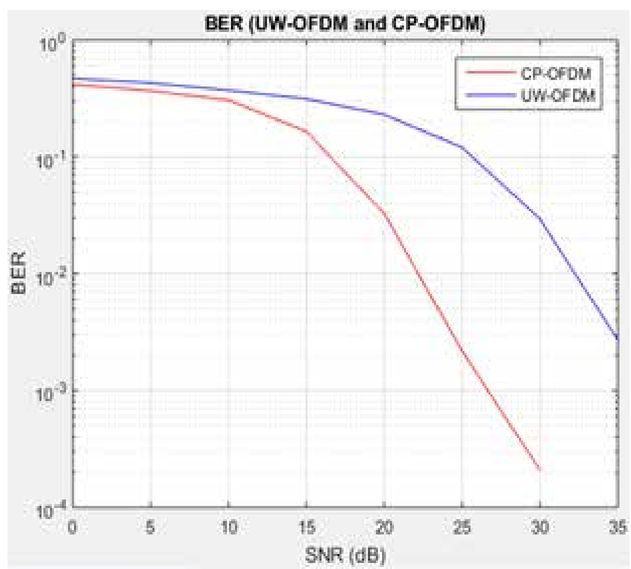


Figure-3: BER comparison for CP-OFDM and UW-OFDM

Table-2: Theoretical BER result for CP-OFDM and UW-OFDM system

	BER	
SNR	**CP-OFDM**	**UW-OFDM**
0	0.4160	0.4591
5	0.3766	0.4284
10	0.2746	0.3711
15	0.1338	0.3084
20	0.0250	0.2464
25	0.0017	0.1226
30	0.0002	0.0136
35	0	0.0022
40	0	0

Throughput comparison

The throughput of CP-OFDM system is compared with the UW-OFDM system, shown in Figure-4 and theoretical values are listed in Table 1. The UW-OFDM system can carry more data bit with same channel capacity than CP-OFDM system.

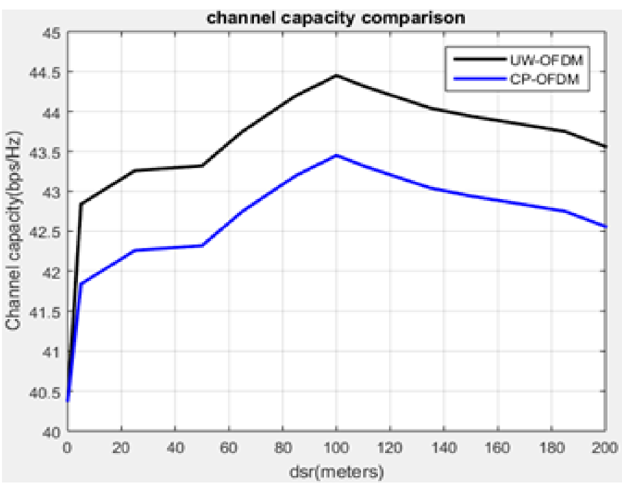


Figure-4: Throughput between CP-OFDM and UW-OFDM system

Table-3: Theoretical value comparison of throughput of CP-OFDM and UW-OFDM system

	Throughput	
Distance dsr (meters)	CP-OFDM	UW-OFDM
0	40.36	40.38
5	40.82	42.84
10	40.21	43.26
15	40.30	43.32
20	40.70	43.75

Analysis based on Constellation Types

Further we analyzed the performance of various constellation/modulation types used for UW-OFDM system. Here Figure-5 shows that increase in modulation order degrades the BER performance of OFDM system.

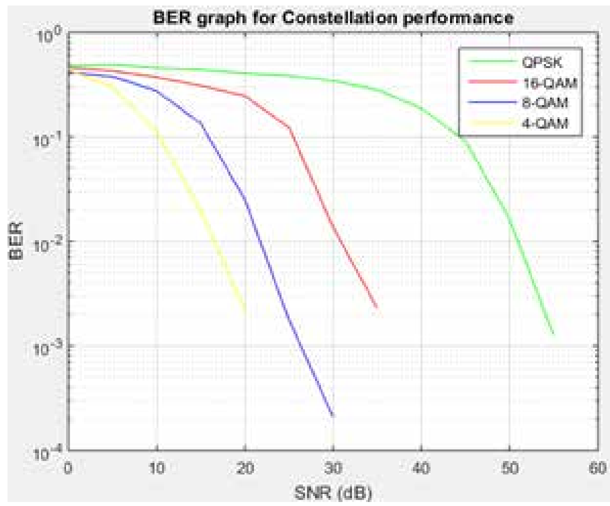


Figure-5: BER analysis for constellation performance of UW-OFDM system

CONCLUSION

This paper focuses on improving channel estimation accuracy in MIMO-OFDM systems, demonstrating the superiority of Bayesian channel estimation with STBC and SVD over CS-based methods. Method-2 exhibits better BER performance than Method-1, indicating enhanced accuracy in channel estimation. Utilizing STBC enables full diversity and diversity gain while mitigating inter-antenna interference, leading to improved power efficiency. Transitioning from cyclic prefix (CP) to unique word (UW) in OFDM frames enhances throughput due to the deterministic nature of UW and increased symbol packing. Additionally, investigating different modulation constellations like 4-QAM, 8-QAM, 16-QAM, and QPSK reveals higher-order schemes offer faster data rates and spectral efficiency at the expense of BER performance, yet find applications in various communication systems like DVB, LAN, MAN, and 4G/5G mobile networks.

REFERENCES

1. Wen, C.-K., Jin, S., Wong, K.-K., Chen, J.-C., & Ting, P. (2015). Channel Estimation for Massive MIMO Using Gaussian-Mixture Bayesian Learning. IEEE Transactions on Wireless Communications, 14(3), 1356–1368.

2. E. G. Larsson, F. Tufvesson, O. Edfors, and T. L. Marzetta,''Massive MIMO for next generation wireless systems'', IEEE Commun. Mag.,vol. 52, no. 2, pp. 186–195,Feb. 2014. [3] B. Vucetic, J. Yuan: Space-Time Coding, Wiley, April 2003.

4. X. Rao, V. K. N. Lau, "Distributed compressive CSIT estimation and feedback for FDD multi-user massive MIMO systems", IEEE Trans. Signal Process., vol. 62, no. 12, pp. 3261-3271, Jun. 2014.

5. Y. Shi, J. Zhang, K. B. Letaief, "CSI overhead reduction with stochastic beam-forming for cloud radio access networks", Proc. IEEE ICC, pp. 5154-5159. [6] S. Nguyen, A. Ghrayeb, "Compressive sensing-based channel estimation for massive multiuser MIMO systems", Proc. IEEE WCNC, pp. 2890-2895.

7. Y. C. Pati, R. Rezaiifar, and P. S. Krishnaprasad, "Orthogonal matching pursuit: Recursive function approximation with applications to wavelet decomposition," in Proc. 27th Annu. Asilomar Conf. Signals, Systems, and Computers, 1993, pp. 40–44.

8. R. Tibshirani, "Regression shrinkage and selection via the lasso," J. Royal. Statist. Soc., Ser. B, vol. 58, no. 1, pp. 267–288, 1996.

9. Ammar, N., & Ding, Z. (2007). Blind Channel Identifiability for Generic Linear Space-Time Block Codes. IEEE Transactions on Signal Processing, 55(1), 202–217. doi:10.1109/tsp.2006.882089

10. Huemer, M., Onic, A., & Hofbauer, C. (2011). Classical and Bayesian Linear Data Estimators for Unique Word OFDM. IEEE Transactions on Signal Processing, 59(12), 6073–6085. doi:10.1109/tsp.2011.2164912

11. M. Huemer, C. Hofbauer, J.B. Huber, "The Potential of Unique Words in OFDM", In the Proceedings of the 15th International OFDM-Workshop, Hamburg, Germany, pp. 140-144, September 2010.

12. A. Onic, M. Huemer, "Direct versus Two-Step Approach for Unique Word Generation in UW-OFDM", In the Proceedings of the 15th International OFDM-Workshop, Hamburg, Germany, pp.145-149, September 2010.

13. Ammar, N., & Ding, Z. (2007). Blind Channel Identifiability for Generic Linear Space-Time Block Codes. IEEE Transactions on Signal Processing, 55(1), 202–217.

14. S. M. Alamouti, "A simple transmit diversity technique for wireless communications," IEEE J. Sel. Areas Commun, vol. 16, pp. 1451–1458, Oct. 1998

15. N. Ammar and Z. Ding, "On blind channel identifiability under space-time coded transmission," in 36th Asilomar Conf. Signals, Syst. Comput., 2002, pp. 664–668.

Advancements in Biomedical Signal Processing: Innovations, Applications, and Future Trends

Priyanka Sandesh Nikam*
✉ priyanka.nikam@vpmmpcoe.org
Aparna Murkar
✉ aparna.murkar@vpmmpcoe.org
Gajanan P. Khapre
✉ gajanan.khapre@vpmmpcoe.org
Pankaj Warak
✉ plwarak@git-india.edu.in

Assistant Professor
Department of Electronics and Telecommunication Engineering
Mumbai University, Mumbai, Maharashtra

ABSTRACT

Biomedical signal processing, combined with advanced technology, plays a vital role in enhancing patient care and empowering individuals with disabilities. This paper explores the integration of biomedical systems with signal processing techniques, including life support and monitoring systems, physiological monitoring devices (ECG, MRI, EEG), and rehabilitation systems. We discuss signal processing methods and techniques, such as state vector machines, hidden Markov models, wavelet transforms, and pattern recognition, employed in biomedical systems. These methods enable the analysis and interpretation of biosignals, providing diagnostic and therapeutic insights. The paper emphasizes the classification of biomedical systems into medical and rehabilitative systems. Medical systems focus on diagnosis and monitoring, while rehabilitative systems aim to support optimal functioning for disabled individuals. Case studies and examples illustrate the impact of biomedical signal processing on healthcare, including early disease detection, improved treatment delivery, and enhanced quality of life for individuals with disabilities. We conclude by highlighting future trends in biomedical systems and signal processing advancements, exploring the potential for personalized medicine, wearable devices, and artificial intelligence in healthcare and rehabilitation.

KEYWORDS *: Signal processing, State vector machine, Hidden markov model, Rehabilitation systems, Wavelet transform.*

INTRODUCTION

Biomedical signal processing has evolved beyond signal analysis, now encompassing applications such as artificial limb development and advanced medical imaging [1]. Quantitative analysis via powerful algorithms aids in diagnostics, employing techniques like filtering and pattern recognition (2). Medical systems diagnose and monitor patients, while rehabilitative systems enhance the functioning of disabled individuals [3-4]. These advancements improve patient treatment and enhance the quality of life for disabled individuals [1-4].

BIOMEDICAL SIGNAL ACQUISITION

Bioelectric signals like EKG, EMG, and EEG require specialized amplifiers and filters for acquisition [1]. Real-time biomedical applications demand high-speed, flexible data acquisition systems with stringent safety measures [2]. Integrated Data Acquisition Units (IDAU) integrate preamplifiers and filters, ensuring signal integrity without distortion [3]. Preamplifiers amplify signals with high input impedance and CMRR, while filters eliminate unwanted signals [4]. Low-pass filters restrict signal frequency, while high-pass filters block DC offset voltage [5].

BIOSIGNAL PROCESSING TECHNIQUE

Support Vector Machine (SVM)

The Electrocardiogram (ECG) is crucial for diagnosing heart conditions, with distinctive P, QRS, and T-waves indicating different heart activities. However, detecting these waves automatically is challenging due to their low amplitudes and signal noise. Support Vector Machines (SVM) are employed for wave classification, offering significant advancements in pattern recognition. An algorithm is developed for wave detection, involving steps such as ECG signal acquisition, baseline wander mitigation, slope normalization for QRS enhancement, and SVM-based classification. SVM-trained models detect QRS complexes, which are then replaced with baselines for further analysis. The process is repeated for T-wave detection, followed by P-wave identification after QRS and T-wave removal.

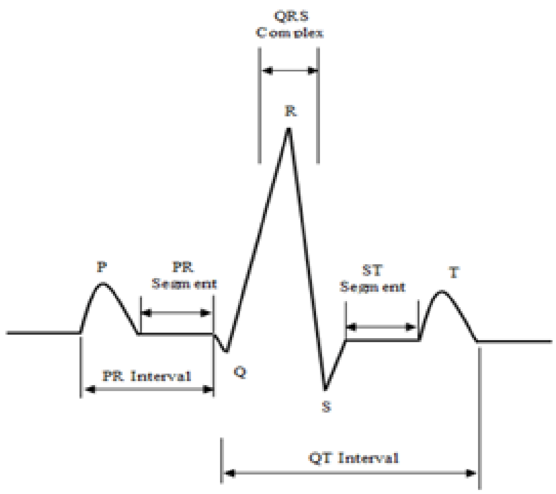


Figure 1. A typical ECG signal waveform.

Fig.1 ECG signal

As illustrated in Fig.1, the first deflection, termed the P-wave, originates from the depolarization of the atria. The QRS-complex, characterized by significant amplitude, arises from the depolarization of the ventricles.

Hidden Markov Models

In random signal processing, models are essential for efficient signal processing and parameter estimation. While exact models are rare in biomedical applications, Markov Chain Processes are valuable for biomedical signal processing. Markov chains consist of synchronized states transitioning with specific probabilities. Hidden Markov Models are widely used in speech recognition and biomedical fields, aiding in the analysis of various signals like EEG, EMG, and bioacoustic signals. Ongoing research explores their potential in detecting physiological conditions.

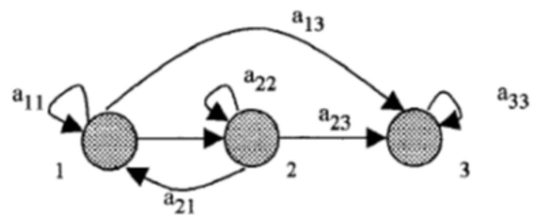


Fig. 2: A three states markov chain model

Neural Networks

Neural networks are effective in analyzing biomedical signals like EMG due to their learning capacity and adaptability. In an EMG classification system (Fig. 3), surface electrodes capture signals post-finger movement, undergo FFT analysis, and feed into a network with 10 input, 7 hidden, and 5 output processing elements. The network matches signals to desired outputs, categorizing EMG signals based on finger movements.

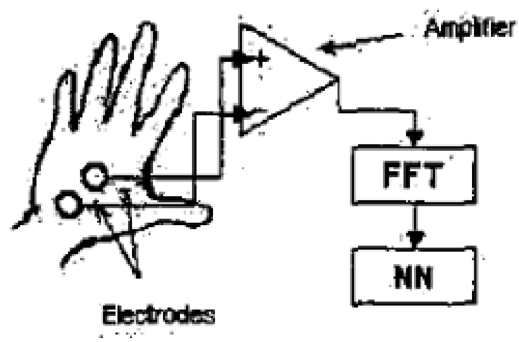


Fig. 3: Schematic diagram of EMG classification system.

Other techniques

Biosignal processing employs techniques like STFT (Short-Time Fourier Transform) and Wavelet Transform. In STFT, a fixed-width window function is moved across the signal to compute its inner product. Wavelet Transform decomposes a signal using basis functions derived from dilations, contractions, and shifts of a wavelet prototype. Unlike STFT, Wavelet Transform's wavelets vary in width across frequencies.

BIOMEDICAL SYSTEMS

Medical Systems

In medical systems, platforms like Physiotrace and Boom-NT provide real-time access to patient data through on-screen processing and display [13]

[14]. Physiotrace integrates hardware, software, and DSP algorithms for biomedical data acquisition, centralization, and visualization, while Boom-NT offers a user-friendly interface for modeling and executing signal processing strategies [13][14]. Textile-based wearable biomedical systems, featuring sensor-embedded jackets, capture signals for further analysis [15].

Rehabilitate systems

Systems utilizing EEG and EMG signals enable control of cursor movement and left-click commands, serving as human-computer interfaces for disabled individuals [16]. These systems differentiate commands using amplitude thresholds and power spectral density estimations, offering affordable DSP-based solutions [16]. Specialized products include an EMG-controlled telephone interface for disabled operators [17]. Innovations include an EMG-based robot for human support, featuring arm and wrist control segments and a graphical feedback display [18]. Another innovation is an EMG-based human-robot interface for rehabilitation aid, integrating signal processing, manipulator, rehabilitation program, and biofeedback [19]..

FUTURE SCOPE

Biomedical signal processing holds great promise, fueled by global research and advancements in real-time systems, wearable technology, and embedded systems. Key areas of interest include the convergence of micro-nano-bio technologies, refining processing techniques with hidden Markov models, and exploring bioinformatics and AI integration. The future landscape anticipates transformative innovations driven by interdisciplinary collaborations, advanced sensor technologies, and cloud and edge computing, revolutionizing healthcare and personalized medicine.

CONCLUSION

In summary, biomedical signal processing is driving innovation in healthcare, empowering real-time monitoring, diagnosis, and rehabilitation. Advanced techniques like Support Vector Machines, Hidden Markov Models, and Neural Networks enable insightful analysis of biosignals. Medical systems prioritize diagnosis, while rehabilitative systems focus on enhancing quality of life for the disabled. Future advancements in wearable tech, AI, and cloud computing promise further breakthroughs in personalized medicine. With ongoing research, biomedical signal processing will remain pivotal in improving patient outcomes and human well-being.

REFERENCES

1. Y. Attikiouzcl, “Biomedical signal Processing: present and future,” Proc. Of the Fifth Int. Symposium on Signal Processing and Its Applications, 1999. ISSPA’ 99, vol. 1, pp.2.
2. G. Bolmsjo, H.Neveryd, and H. Eftring., “Robotics in rehabilitation,” IEEE Trans. Rehab. Eng. Vol. 3, issue: 1, pp. 77-83. Mar. 1995.
3. M. Kassier, “Special Issue on Robotics in Health Care.” Cambridge: Cambridge University Press, vol. 11, no. 6.
4. C. Thornett, “Technical aids for the disabled,” IEEE Review, vol. 3, issue: 5, pp. 165-168. May 1989.
5. B.S. Drakulic, S.J. Berry, M.N. Gold, and Z.Konstantinovic., “ A real time data acquisition and signal processing unit for biomedical applications,” Proc. Int. Conf. IEEE Eng. Med. Bio. Soc., vol. 3, 1988, pp. 1260-1261.
6. S. Solis-Bustos and J. Silva-Martinez, “Design Considerations for biomedical signal interferences,” 3rd Int. Workshop on Design of Mixed-Mode Integrated Circuits and Applications, 1999, pp. 187-191.
7. B. U. Kohler, C. Henning, and R. Orglmeister, “The principles of software QRS detection,” IEEE Eng. In Med. And Bio., pp. 42-47, (2002).
8. S. S. Mehta, N.S. Lingayat, “ Biomedical Signal Processing Using SVM”, ET-UK International Conference on Information and Communication Technology in Electrical Sciences(ICTES 2007), Dec. 20-22, 2007, pp. 527-532.
9. A. Cohen, “Hidden Markov Models in Biomedical Signal Processing”, 20th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, Vol. 20, No 3, 1998.
10. A. Hiraiwa, K. Shimohara, and Y. Tokunaga., “EMG pattern analysis and classification by neural network”, Proc. IEEE Int. Conf. Syst. Man, Cybern, vol.3, 1989. pp. 1113-1115.
11. D. Gabor,” Theory of Communication,” J. IEE, vol. 93, issue: 3, pp. 429-457. 1946.

12. M. Akay and C. Mello., "Wavelets for biomedical signal processing," Proc. 19th Int. Conf. IEEE Eng. Med. Biol. Soc, vol. 6, 1997, pp. 2688-1691.

13. J. De jonckheere, R. Logier, A. Dassonneville, G. Delmar, C. Vasseur, "Physio Trace: An efficient toolkit for biomedical signal processing", proc. Of the 2005 IEEE, Engineering in medicine and Biology 27th annual conference shanghai, china, September 1-4, 2005.

14. Timo Bretschneider, Boris R. Bracio, "BOOM-NT: A Visual Tool For Biomedical Signal Processing", proc. 19th international conference- IEEE/EMBS Oct. 30-Nov. 2, 1997 Chicago, IL. USA.

15. Sungmee Park, Sundaresan Jayaraman," Smart Textile-Based Wearable Biomedical Systems: A Transition Plan for Research to Reality", IEEE trans. On Information Technology in Biomedicine, vol. 14, no. 1, January 2010.

16. A. B. Barreto, S.D. Scargle, M.A. Adjouadi,. " A practical EMG-based human-computer interface for users with motor disabilities", J Rehabil Res Dev., vol. 37, issue: 1, pp. 53-63. Jan-Feb. 2000.

17. Y. L. Chen, j. S. Lai, J.J. Luh, T.S. Kuo., "SEMG-controlled telephone interface for people with disabilities," J Med Eng. Technical., vol. 26, issue 4, pp. 173-176 Jul-Aug. 2002.

18. O. Fukuda, T. Tsuji, H. Shigeyoshi, and M. Kaneko., "An EMG-controlled human supporting robot using neural network." Proc. IEEE/RSJ Int. Conf. intell. Robot. Syst. IROS '99., vol. 3, 1999, pp. 1586-1591.

19. O. Fukuda, T. Tsuji, H. Shigeyoshi, and M. Kaneko., " EMG-based human robot interface for rehabilitation aid," Proc. IEEE int. Conf. Robot. Automat., vol. 4, 1998, pp. 3492-3497.

E-Waste EcoHub: Facility Locator

Aarti M Karande
✉ aartimkarande@spit.ac.in

Hrishikesh Parkar
✉ hrishikesh.parkar22@spit.ac.in

Sanchit Gaikwad
✉ sanchit.gaikwad22@spit.ac.in

Masters of Computer Application
Sardar Patel Institute of Technology
Mumbai, Maharashtra

ABSTRACT

With the relentless pace of technological innovation, the electronic waste (e-waste) crisis has become a pressing global concern, demanding sustainable solutions. This research paper introduces ”E-Waste EcoHub,” an innovative platform designed to tackle the challenges associated with improper disposal of electronic devices. E-Waste EcoHub serves as a centralized hub for users, offering a multifaceted approach to responsible e-waste management. Key objectives include facilitating proper disposal through location services, educating users on the environmental impacts of e-waste. The existing e-waste management landscape faces challenges such as limited accessibility, lack of awareness, and fragmented information. This paper discusses the unique contributions of E-Waste EcoHub in the context of existing e-waste management initiatives, highlighting its potential to enhance user engagement, raise environmental awareness, and contribute to a more sustainable approach to e-waste disposal.

INTRODUCTION

In our fast-paced world, we use electronic devices like phones and computers every day. But what happens when these devices get old and we don't need them anymore? Often, they end up as electronic waste, or ”e-waste,” which can be harmful to the environment and our health.

The E-Waste EcoHub is here to help! It's a website that helps you find the closest place to safely get rid of your old electronics. But that's not all – it also teaches you why it's so important to dispose of them properly. You'll learn about the harmful stuff in your old devices and how it can affect our planet and people if not handle

Electronic waste, commonly known as e-waste, represents a growing and significant environmental challenge in our technologically driven society. E-waste encompasses discarded electronic devices, ranging from smartphones and laptops to household appliances and industrial equipment. The rapid evolution of technology has led to increased consumption and shorter product life cycles, resulting in a surge of electronic waste worldwide. Improper disposal of e-waste poses environ- mental and health risks due to the presence of hazardous mate- rials. Addressing this issue requires comprehensive strategies, including responsible recycling, awareness campaigns, and the development of innovative solutions to manage and mitigate the impact of e-waste on our planet.

LITERATURE SURVEY

E-Waste Challenge

The rapid advancement of technology has led to a surge in the production and disposal of electronic devices, resulting in a growing concern about electronic waste (e-waste) management. E-waste, composed of discarded electronic products, poses significant environmental and health risks if not handled properly. This literature review examines key studies and findings related to e-waste management, environmental consequences, and initiatives promoting responsible disposal practices.

Scale of the E-Waste Challenge

The escalating volume of e-waste globally has been a central focus of research. Studies, such as the one by Balde et al. (2017), emphasize the exponential growth of e-waste and project future challenges if effective management strategies are not implemented.

The quantification of e-waste generation serves as a foundation for understanding the urgency of sustainable disposal solutions.

There is a need for e-waste management as e-waste components may cause severe health risks and environmental damage, when crude, unscientific methods are applied for recovery of useful components. There is a need to encourage recycling of all useful and valuable material from e-wastes to preserve the natural resources.

Environmental Impact of Improper E-Waste Disposal

Research consistently highlights the environmental consequences associated with improper e-waste disposal. Hazardous substances present in electronic devices, including heavy metals and toxic chemicals, can contaminate soil, water, and air. Studies by Song et al. (2015) and Awasthi et al. (2016) delve into the leaching of pollutants from e-waste and their adverse effects on ecosystems.

Global Trends and Alarming Projections

The United Nations Environment Programme (UNEP) re- ports a concerning annual increase of 40% in electronic waste (e-waste) globally, making it the fastest-growing waste category. This surge results in the generation of 20 to 50 million metric tons of e-waste each year, constituting over 5% of urban solid waste, with some developing countries anticipating a staggering 500% growth in volume over the next decade.

Specifically, in India, the estimated volume of e-waste reached 0.8 million tons in 2012. The Controller and Audi- tor General's (CAG) report highlights the significant annual generation of waste in the country, including 7.2 million metric tons of industrial hazardous waste, 4 lakh tonnes of electronic waste, 1.5 million tons of plastic waste, 1.7 million tons of medical waste, and 48 million tons of municipal waste. These figures underscore the urgent need for sustainable and effective e-waste management practices to address the escalating environmental and health concerns associated with this growing waste stream.

Ways of disposing of electronic waste in Kuwait

In a 2020 article authored by Majd Othman in Kuwait, findings indicated that awareness regarding electronic waste disposal methods was at 32.7 percent, with a notable pro- portion expressing interest in sorting their electronic waste. The study, conducted by the Sabah Al-Ahmad Center for Environmental Training at the Kuwait Environmental Pro- tection Society, highlighted a concerning lack of awareness and knowledge, specifically noting that only 10 percent of individuals were informed about appropriate methods for the disposal and recycling of mobile phones. These insights underscore the need for enhanced educational initiatives and awareness campaigns to promote responsible electronic waste management practices among the Kuwaiti population.

The findings revealed that 32.7% of participants actively segregate their electronic devices for proper disposal, while others tend to store or improperly discard them. Participants expressed a strong interest in acquiring knowledge about safer disposal methods, particularly concerning damaged electronic devices.

Furthermore, the survey uncovered that 40% of partici- pants engage in periodic sorting at home, choosing to donate electronic items they no longer require. The study not only highlights current e-waste disposal practices but also under- scores the importance of fostering awareness and community participation in addressing this environmental concern.

To enhance e-waste management, participants suggested establishing collection points in residential areas, intensifying awareness campaigns, and integrating e-waste disposal ser- vices into municipal waste transport initiatives. This holistic approach reflects Kuwait's commitment to proactive measures, emphasizing awareness, responsible disposal practices, and community engagement to effectively tackle the challenges associated with e-waste.

Strategies employed by similar platform to address the e-waste challenge

In the context of e-waste management in Australia, a no- table solution is presented by destroyr.com.au. Their approach involves a dedicated team specializing in the responsible collection of e-waste from various sources, including offices, institutions, and homes. Unlike potentially harmful methods such as smashing, their meticulous recycling process focuses on achieving nearly 100% recyclability.

During the disassembly phase, the team carefully separates components, paying special attention to the removal of alkaline batteries due to their toxicity. Reusable components are preserved, while those storing data undergo irreversible destruction. Techniques such as using powerful magnets for hard drives and industrial shredders for solid-state drives ensure data erasure and permanent damage.

The final stage includes shredding the remaining components into small fragments, with magnets extracting valuable metals like gold, silver, copper, and steel. Bulk quantities of plastic and metal alloys are then sent to recycling sites for further processing.

This website's emphasis on material recycling involves advanced tools to separate materials into usable metals and plastics, contributing to the creation of new hardware and other products. Opting for their e-waste recycling solution not only showcases environmental responsibility but actively reduces the carbon footprint, demonstrating a commitment to sustainability for businesses and individuals in Australia.

PROPOSED METHODOLOGY

The development of E-Waste EcoHub was a meticulous and collaborative effort spanning ten days, driven by a strategic and well-defined process. This journey unfolded in distinct phases, each contributing significantly to the platform's robustness and functionality.

From the initial kickoff, where objectives were aligned with stakeholder input, to the technical implementation phase leveraging the MERN stack, and finally, the testing and refinement stages, every step played a crucial role in shaping E-Waste EcoHub into an effective solution for responsible e- waste disposal.

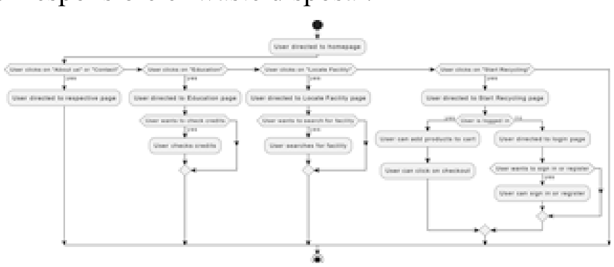


Fig. 1. Flow Chart

Development Process

- Initiation Phase: The E-Waste EcoHub project commenced with a thorough initiation phase during the first two days. This marked a comprehensive project kick- off, aligning the development team with the objectives of E-Waste EcoHub. Extensive discussions took place with stakeholders, including potential users and environ- mental experts, to gather detailed requirements. These interactions ensured a nuanced understanding of the e- waste management ecosystem. The initiation phase also involved formulating an initial design and architectural plan, precisely defining the platform's structure. The MERN stack (MongoDB, Express. js, React, and Node.js) was carefully selected for its adaptability and rapid development capabilities. Clear role assignments and task allocations were established to facilitate efficient resource utilization.
- Technical Implementation Phase: Days 3 to 6 were dedicated to the technical implementation phase. The MERN stack was actively chosen, leveraging MongoDB for the database, Express.js for server development, React for the front-end, and Node. js for the runtime environment. The front-end development team focused on creating a user-friendly interface, emphasizing responsiveness and intuitive design using Next.js. Simultaneously, the back- end development team constructed the server, developed API endpoints, and seamlessly integrated the MongoDB database using Express. js. Rigorous testing protocols were implemented to identify and rectify any integration issues, ensuring the robustness and stability of the E- Waste EcoHub platform.
- Feature Development and Testing: Days 7-8 were dedicated to feature development and testing. Key features critical to the E-Waste EcoHub's functionality, such as location services for identifying nearby collection centers, an educational pop-up system detailing the harmful components of e-waste, and a credit-based reward system for users contributing to responsible disposal, were implemented. User testing involved individuals from diverse backgrounds, providing valuable feedback for refinement and optimization of features.

- Final Phase: The final phase, spanning Days 9-10, focused on thorough testing to ensure that all features of E- Waste EcoHub operated seamlessly. Following successful testing, E-Waste EcoHub was deployed to a production server, making it accessible to users concerned with responsible e-waste disposal. This deployment marked the culmination of the development process, showcasing a fully functional and refined E-Waste EcoHub platform ready to address the challenges posed by electronic waste on a global scale.

Methodologies Implemented

1) Location Services: We integrated Mapbox for location services, leveraging spatial indexing and nearest neighbor search techniques to identify and map the closest facilities based on the user's location. The utilization of Mapbox enhances the precision and responsiveness of our location-based services, contributing to a seamless and effective user experience in accessing e-waste disposal facilities.

2) User Device Input and Credit Points: To assign credit points based on user input regarding their old device models, we employed a data classification algorithm. This algorithm categorizes and evaluates the inputted device models, estimating the amount of precious metals recoverable from each model. Our approach utilizes a machine learning classification model trained on historical data.

3) Educational Pop-ups: For the educational pop-ups regarding the harmful components of e-waste, we implemented a content recommendation algorithm. This algorithm tailors the information presented to users based on their preferences and historical interactions with the platform. It enhances user engagement by providing relevant and personalized educational content.

4) Monetizing Responsible E-Waste Disposal: The credit-based reward system, designed to monetize responsible e-waste disposal, incorporates an algorithm to calculate and allocate credits. This algorithm considers factors such as the type and quantity of e-waste disposed of properly, as well as the environmental impact and recycling efficiency.

5) Data Analytics for Trends and Insights: We employed various data analysis algorithms to process and analyze trends in e-waste generation, export patterns, and user behavior. These include statistical algorithms for trend analysis, clustering algorithms for pattern identification, and predictive modeling for forecasting future trends.

IMPACT ANALYSIS

Environmental Impact

- E-Waste EcoHub is poised to make a significant contribution to environmental conservation by fostering responsible e-waste disposal practices. One of the key impacts is evident in the reduction of improperly discarded electronic devices. By providing a platform that guides users to certified e-waste collection and recycling facilities, the project directly addresses the environmental risks associated with haphazard disposal. Furthermore, the credit-based incentive system acts as a catalyst for proper recycling, facilitating the recovery of precious metals and materials from electronic devices. This not only minimizes the environmental footprint of e-waste but also reduces the demand for new resource extraction, promoting a more sustainable use of finite resources.

Social Impact

- The social impact of E-Waste EcoHub extends beyond the individual user to the broader community. The inclusion of educational pop-ups within the platform serves as a valuable tool for raising awareness and imparting knowledge about the harmful components of e-waste. Users, including students, educators, and administrators, engage in discussions that foster a deeper understanding of the environmental and health implications associated with improper disposal practices. The introduction of discussion boards and community forums provides a collaborative space where experiences and insights can be shared, cultivating a sense of community and shared responsibility toward sustainable e-waste management practices.

Economic Impact

- E-Waste EcoHub holds the potential for economic impact on multiple fronts. The implementation and ongoing maintenance of the platform may contribute to job creation, particularly in areas related to e-waste collection, recycling, and platform development. The credit-based reward system introduces an economic incentive for users to actively participate in responsible e-waste disposal. This not only encourages greater engagement with the platform but also supports local economies involved in the recycling process. By aligning environmental responsibility with economic incentives, E-Waste EcoHub establishes a framework where users are not only contributing to sustainability but also benefiting economically from their actions.

SECURITY CONSIDERATIONS

Security considerations take center stage in this deployment, demanding robust measures to protect user data and system integrity. Implementation of stringent firewalls, regular security audits, and encryption protocols for data transmission and storage are pivotal for creating a secure environment. Ensuring the security of the E-Waste EcoHub platform is paramount to protect user data, maintain the integrity of the system, and foster user trust.

Data Encryption

- In-Transit Encryption: Implement secure communication protocols such as HTTPS to encrypt data transmitted between clients and servers, preventing eavesdropping and man-in-the-middle attacks.
- At-Rest Encryption: Utilize encryption techniques to safeguard sensitive data stored in databases, ensuring that even if unauthorized access occurs, the data remains unreadable.

User Authentication and Authorization

- Strong Password Policies: Enforce robust password policies, including complexity requirements and regular password updates, to enhance the security of user accounts.
- Multi-Factor Authentication (MFA): Implement MFA to add an additional layer of security, requiring users to verify their identity through multiple means.

Role-Based Access Control (RBAC)

- Principle of Least Privilege: Implement RBAC to ensure that users have only the minimum access necessary to perform their tasks. This limits potential damage in case of a compromised account.

Secure APIs

- API Security: Apply proper authentication and authorization mechanisms to secure APIs. Use API tokens or OAuth for secure data exchange between the front-end and back-end components.

Logging and Monitoring

- Security Event Logging: Implement comprehensive logging of security-relevant events to enable timely detection and response to security incidents.
- Real-Time Monitoring: Employ real-time monitoring tools to detect and respond to suspicious activities promptly.

Regular Security Audits

- Penetration Testing: Conduct regular penetration testing to identify and address vulnerabilities. Hire external security experts to simulate real-world attacks and assess the resilience of the system.

Vendor and Third-Party Security

- Third-Party Risk Assessment: Assess and validate the security measures implemented by third-party services or libraries integrated into the platform to prevent potential vulnerabilities introduced by external dependencies.

CHALLENGES FACED

1) User Adoption and Awareness: Encouraging users to actively engage with the platform and follow proper e-waste disposal practices may be challenging. Raising awareness about the platform's benefits and functionality is essential.
2) Data Security: Given the sensitive nature of electronic waste, ensuring robust data security measures to protect user information and maintain the confidentiality of disposed devices becomes a significant challenge.
3) Community Engagement: Fostering community

engagement and participation in e-waste collection campaigns may be challenging. Establishing trust and convincing individuals and businesses to actively contribute to the platform is crucial.

4) Scaling and Expansion: Scaling the platform to accommodate a growing user base and potential expansion to new geographic regions may present challenges in terms of infrastructure, logistics, and regulatory compliance.

Fig. 2. Home Page

FUTURE WORK

Expanding the geographic coverage of E-Waste EcoHub is paramount for a broader impact. Future work will focus on establishing partnerships with e-waste management facilities on an international scale. Adapting the platform to comply with diverse regulatory environments and cultural contexts will be essential for successful expansion.

Fig. 3. Education Page

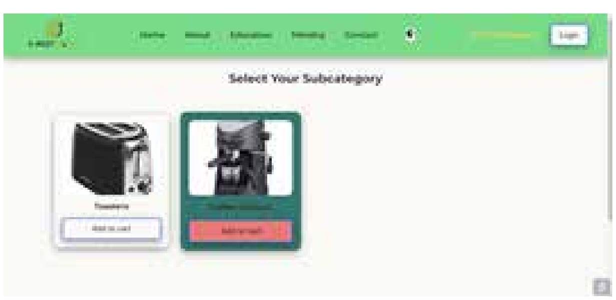


Fig. 4. Add-to-cart Page

Fig. 5. Facilty Page

CONCLUSION

In conclusion, the development and implementation of the E-Waste EcoHub project represent a significant step toward addressing the pressing challenges posed by electronic waste. This comprehensive platform integrates innovative technologies, educational initiatives, and incentives to promote responsible e-waste disposal practices. Through the use of the MERN stack, geospatial algorithms, and data classification algorithms, the platform provides users with a user-friendly interface for locating nearby e-waste collection facilities, understanding the environmental impact of e-waste, and earning incentives through proper disposal.

The project's impact spans across environmental, social, economic, and technological dimensions. E-Waste EcoHub contributes to waste reduction, resource recovery, and in- creased awareness of e-waste's environmental consequences. The platform fosters community engagement, knowledge sharing, and responsible behavior among users. Economically, the credit-based reward system incentivizes recycling, potentially contributing to job creation and supporting local economies.

Technologically, E-Waste EcoHub showcases the successful integration of cutting-edge technologies for efficient and scalable solutions. The security considerations, including encryption, authentication, and continuous monitoring, ensure the protection of user data and the integrity of the platform.

As the project moves forward, there are exciting opportunities for future work. This includes geographic expansion, enhanced educational content, advanced machine learning applications, and the integration of emerging technologies like blockchain and IoT.

The incorporation of gamification elements, the development of dedicated mobile applications, and continuous security audits will further enhance the platform's effectiveness and user experience.

REFERENCES

1. Bhat, V. and Patil, Y. (2014). E-waste consciousness and disposal practices among residents of Pune city. Procedia - Social and Behavioral Sciences, 133, 491-498.
2. Mehra HC. Tribune. 2004. PC waste leaves toxic taste.
3. Baud I, Grafakos S, Hordjik M, Post J. Quality of life and alliances in solid waste management. Cities. 2001;18:3–12.
4. en.wikipedia.org/wiki/Electronic-waste.
5. R. Nicole, "Title of paper with only first word capitalized," J. Name Stand. Abbrev., in press.
6. Dahl R. Who pays for e-junk? Environ Health Perspect. 2002;110:A196–9.
7. Agarwal R, Ranjan R, Sarkar P. New Delhi: Toxics Link; 2003. Scrapping the hi-tech myth: Computer waste in India.
8. A review on recovery processes of metals from E-waste: A green perspective. Department of Environmental Science, SRM University- AP, Amaravati, Andhra Pradesh 522 240.
9. Metallic resources in smartphones. Bookhagen, D. Bastian, P. Buchholz, M. Faulstich, C. Opper, T. Prohaska, Koeberl. University of Vienna, Department of Lithospheric Research, Althanstrasse 14, 1090, Vienna, Austria German Mineral Resources Agency (DERA) at the German Federal Institute for Geosciences and Natural Resources (BGR), Wil- helmstrasse 25-30, 13593, Berlin, Germany
10. CPCB — Central Pollution Control Board
11. Metal Extraction Processes for Electronic Waste and Existing Industrial Routes: A Review and Australian Perspective. by Abdul Khaliq,Muhammad Akbar Rhamdhani *ORCID, Geoffrey Brooks and Syed Masood. Faculty of Science, Engineering and Technology, Swinburne University of Technology, Hawthorn, VIC 3122, Australia
12. EMEW Clean Technology. https://emew.com/ewaste-recycling/
13. https://kuwaittimes.com/survey-on-ways-of-disposing-of-electronic- waste-in-kuwait/
14. https://www.destroyr.com.au/

Emotion Detection using Machine Learning

N. T. Pujari
✉ ntpujai@coep.sveri.ac.in

Maheshwari Shirke Patil
✉ maheshwarikpatil@coep.sveri.ac.in

Shreya Wakade
✉ shreyahwakade@coep.sveri.ac.in

Subhada Deshmukh
✉ shubhadardeshmukh@coep.sveri.ac.in

Department of Electronics and Telecommunication
SVERI's College of Engineering, Pandharpur, Punyashlok
Ahilyadevi Holakar Solapur University
Maharashtra

ABSTRACT

The article discusses using facial expressions to identify seven emotional states such as happy, sad, neutral, angry, fearful, and disgusted. By using the coefficients derived from facial expressions as input features, both the KNN classifier and MLP neural network were applied to categorize or classify the observed emotional states, likely aiming to assess the effectiveness of these algorithms in recognizing and distinguishing between different emotions based on facial expressions. The research methodology includes gathering varied facial expression datasets covering a wide range of emotions such as happiness, sadness, anger, surprise, fear, disgust, and neutrality. Through intensive training, machine learning models are trained to identify intricate patterns within facial expressions, facilitating precise and instantaneous emotion detection. The study evaluates how accurately models identify emotions, using established datasets to measure performance in terms of accuracy, recall, and overall effectiveness. This research provides valuable insights into emotion detection through facial expressions and highlights its significance in shaping the future of interactive technology. here are some key points like human-computer interaction, psychology studies and therapy. In essence, the capacity to recognize and understand emotions from facial expressions carries extensive implications, shaping the future terrain of interactive technology. It fosters more intuitive, individualized, and emotionally attuned interactions.

***KEYWORDS** : KNN classifier, MLP neural network algorithm, Facial expression analysis, Facial expression datasets.*

INTRODUCTION

Emotion detection through facial expression analysis has emerged as a dynamic and transformative field, leveraging real-time camera technology to interpret human emotions [4]. By harnessing sophisticated algorithms and real-time image processing techniques, this innovation enables the instantaneous recognition and understanding of emotional states based on facial cues. This introduction explores the advancements in emotion detection using facial expressions, facilitated by the integration of real-time camera systems, and delves into its significance across various domains, from human-computer interaction to psychological studies.[4]

Facial expressions play a crucial role in communicating human emotions, serving as primary indicators of our feelings [4]. Often, these expressions act as nonverbal channels of emotional communication, providing tangible cues to help determine the sincerity of an individual's emotions. With advancements in machine learning techniques, emotion detection through facial expressions has become a compelling area of research. We explore the significance of this technology in deciphering human emotions and delve into the methodologies and challenges associated with building accurate and reliable emotion recognition systems.

This cutting-edge field utilizes sophisticated machine learning methods, including neural networks and deep learning, to scrutinize facial features, expressions, and subtle micro- expressions. Through extensive training on large datasets containing a variety of facial images portraying different emotions, machine learning models adeptly identify intricate patterns indicative of distinct emotional states. This paper delves into the realm of emotion detection through facial expression analysis using machine learning algorithms.

This comprehensive investigation of emotion detection via facial expression analysis, specifically integrating the CNN algorithm [3] with real-time camera technology, highlights the transformative prospects within this interdisciplinary realm. Its objective is to illuminate the methodologies, hurdles, and extensive implications for future technological progress and diverse applications across domains.

Advancements in machine learning techniques, particularly the application of the CNN algorithm, have propelled emotion detection through facial expressions to the forefront of research and innovation. This algorithm, known for its simplicity and effectiveness in classification tasks, plays a pivotal role in analysing facial features and expressions. It scrutinizes intricate patterns within facial data to categorize emotional states accurately.

This technology includes the fusion of real-time camera technology and sophisticated algorithms allowing for the instantaneous recognition and understanding of these emotional states, thereby decoding the subtle nuances embedded within facial expressions. This technology utilizes sophisticated algorithms and data-centric models to precisely decipher facial expressions, enabling accurate recognition and classification of human emotions.

METHODOLOGY

Algorithms used

1) The preferred approach for analysing images, the Convolutional Neural Network (CNN), stands as the most widely used method [9]. Distinguished from a multi-layer perceptron (MLP) by its inclusion of hidden layers termed convolutional layers, the method proposed here relies on a two-tier CNN framework [9]. For this technology, we have acquired a comprehensive dataset comprising diverse images. This collection encompasses a wide range of visual content, including distinct categories and subjects. The dataset incorporates various images presenting diverse scenes, objects, or individuals, offering a rich and varied set of visual information for analysis and processing.

   The utilization of libraries in technology development streamlines the process, augments functionality, encourages collaboration, and ensures compatibility, ultimately contributing to the creation of more efficient, innovative, and robust technological solutions.

2) The Keras preprocessing module, part of the Keras deep learning library, provides a collection of utility functions to help with loading, preprocessing, and augmenting image data.

   These functionalities are especially useful when working with image datasets in deep learning applications, such as convolutional neural networks (CNNs) [1] or other neural network architectures that process visual data. There are some specific layer classes in keras layers (‘Dense’, ‘Dropout’, ‘Flatten’) where the ‘Dense’ layers are fully connected layers where each neuron is connected to every neuron in the preceding and succeeding layers, ‘Dropout’ layers are used to mitigate overfitting by randomly setting a fraction of input units to zero during training, which helps in preventing the network from relying too heavily on certain neurons, ‘Flatten’ layers are used to flatten the input, converting multi-dimensional data into a one- dimensional array [7]. This is often used when transitioning from convolutional layers to fully connected layers.

3) Certain models integrate conventional neural networks with layers or modules inspired by Support Vector Machines (SVM). These hybrid architectures harness the ability of neural networks to learn representations while integrating SVM principles to enhance their classification capabilities.[4] In the realm of computer vision, a fusion of Support Vector Machines (SVMs) and Convolutional Neural Networks (CNNs) has been

employed. Specifically, features extracted from CNNs can be inputted into an SVM for the ultimate classification. This blended strategy has proven effective in addressing diverse challenges related to image classification.

4) Image processing encompasses a range of mathematical operations and transformations that are employed on images. Image processing includes steps like Pixel representation, Transformation functions, Fourier transform [2]. Pixel representation refers to the way in which digital images are composed of individual picture elements, or pixels [2]. Each pixel corresponds to a tiny unit of the image and contains information about its colour and intensity. The combination of pixels creates the overall visual representation of an image. Transformation functions in image processing involve altering the appearance of an image through various operations. These operations can include scaling, rotation, translation, and other geometric transformations. Transformation functions are applied to modify the spatial characteristics of an image without changing its content. Fourier transform is a mathematical operation used in image processing to analyse the frequency content of an image [5]. It decomposes an image into a set of sinusoidal functions, revealing the different frequency components present in the image. This is particularly useful for tasks such as image filtering, compression, and understanding the distribution of patterns in an image.

Proposed Algorithm steps

1) Real time input through web camera
2) Facial expression detection
3) Feature extraction
4) Classification
5) Results

Image recognition is a broader term that encompasses tasks such as image classification but extends to identifying and detecting specific objects or patterns within an image. It involves understanding the content of an image at a more detailed level.

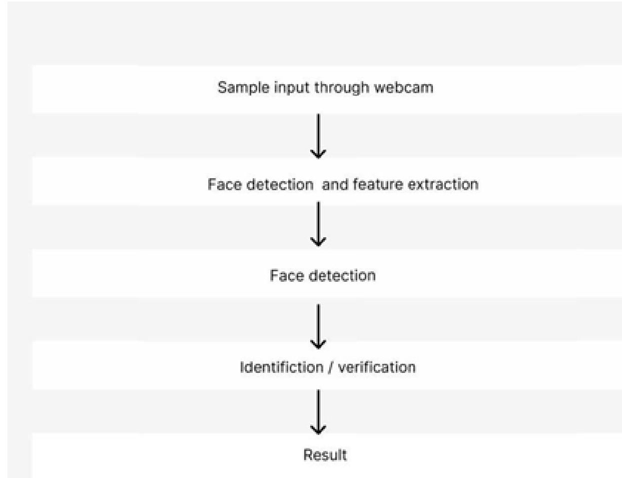


Fig. 1

As shown in above figure fig(a), It represents the flow chart of the processing which is required for the emotion detection using machine learning. It describes all he steps serially which are used for this process

RESULTS AND DISCUSSION

Discussion

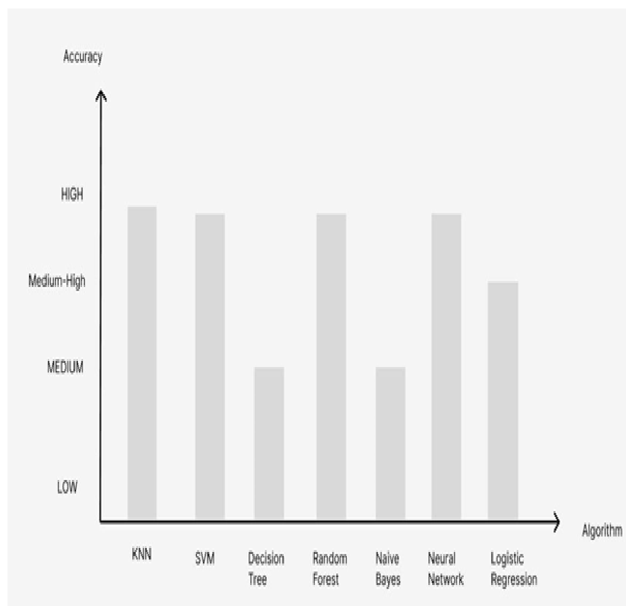


Fig. 2

As we can see in the above fig [2], it shows the accuracy level of different algorithms in machine learning. KNN is an instance-based algorithm that does not make strong decisions. It is a kind of recommended system.

KNN is very sensitive to noisy data. Where SVM is used for moderate data sets, image classifications, and text categorization. A neural network is used for handling complex relationships, image processing, and language processing. It has deep learning capabilities. The neural network requires substantial computational resources. It is used for large-scale data sets. While logistic regression has very limited linear decision boundaries. Logistic regression estimates probabilities using a logistic function. It is mainly used for medical outcome prediction and the marketing field.

Sample output images [1]

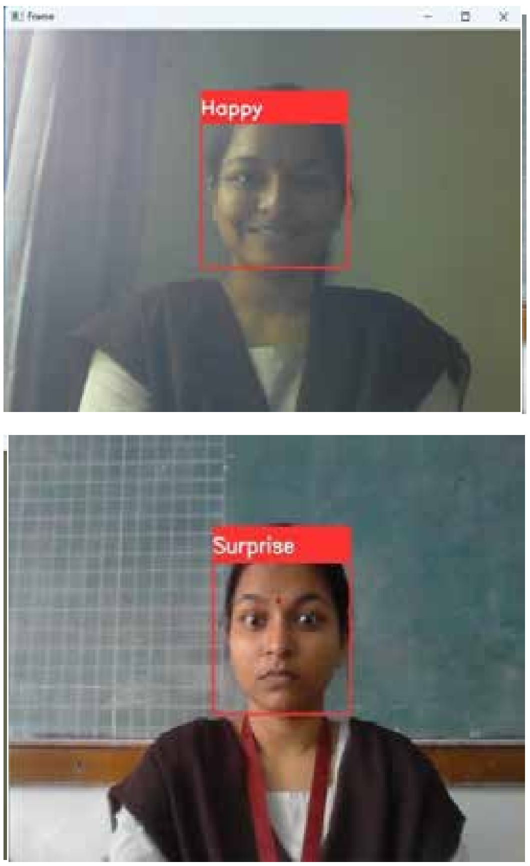


Fig. 3

As it is shown in above figure fig(a), It shows the clear output (Happy, Surprised) where the input is taken through the real-time camera or webcam. The output changes frequently because it takes input live that is why a single little change can also make the output different so the meaning is that it is very realistic for user to experience the changes in their emotions frequently.[2]

Fig.4

As shown in the above figure fig(b), shows that the user is angry emotion. where we can see those changes in facial expression where the edges of the lips are a little bit moving towards the downside and the distance between the eyebrows and eyes is comparatively less than the Fig (a) where the surprised emotion is detected. So basically it focuses on every little detail and changes appeared on face.[3]

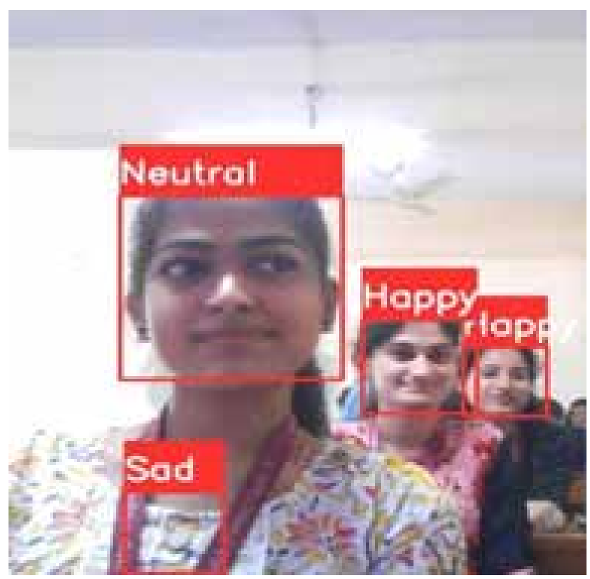


Fig.5

Figure fig(c) shows that if the user wants to take multiple outputs in one frame. It is possible to detect the emotions of multiple people at the same time.

Comparing literature result

No	Year	Title	Author's name	Methodology	Results	Weakness
1	2015	Dynamic Facial Emotion Recognition from 4D Video Sequences	Suja, Kalyan Kumar, Shikha Tripathi	Support vector machine classificati on, feature extraction	recognize the emotions from the video sequences	Difficult to recognize emotion when objects or persons are moving randomly in videos
2	2014	Emotional Healthcare System: Emotion Detection by Facial Expressions Using Japanese Database	Somchanok Tivatansakul, and Michiko Ohkura Supadchaya Puangpontip, and Tiranee Achalakul	Support vector machine learning	It has an approach which applies a pattern recognitio n technique to classify the emotions	It has an issue that includes recognition of similarity in facial expressions that was caused by confusing different emotions.
3	2020	Facial emotion recognition using convolutional neural networks (FERC)	Ninad Mehen dale	Convoluti onal neural network (CNN)	The final predicted output of emotion using background removal	Face pose appearance is a big issue
4	2015	A Comparative Study on Different Approaches of Real-Time Human Emotion Recognition based on Facial Expression Detection	Anurag De Ashim Saha	Facial feature extraction, SVM classification	Fully automatic real-time facial expression recognition	It is also unable to recognize compound or mixed Emotions.
5	2021	Real Time-Employee Emotion Detection system (RtEED) using Machine Learning	Chandraprabha K S Shwetha A N, Kavitha M, Dr. R Sumathi	Viola Jones algorithm is used to detect face	Identified emotion displayed to the employee along with the captured image.	It works well only for the frontal images

CONCLUSION

In summary, the integration of facial expression analysis and real-time camera technology in machine learning has revolutionized emotion detection. This innovative approach allows instant understanding of human emotions, yielding valuable insights across various applications. The synergy of sophisticated algorithms and image processing techniques enables precise recognition of emotional states, advancing human-computer interaction, psychological studies, and therapy. Program efficiency relies on well-trained models, with age and gender being critical factors. To enhance accuracy, expanding the dataset to cover diverse age groups and genders is essential. Future improvements can involve adding additional features to enhance performance.

REFERENCES

1. Suja, Kalyan Kumar, Shikha Tripathi "Dynamic Facial Emotion Recognition from 4D Video Sequences" (2015 IEEE)

2. Somchanok Tivatansakul, and Michiko Ohkura Supadchaya Puangpontip, and Tiranee Achalakul. "Emotional Healthcare System: Emotion Detection by Facial Expressions using Japanese Database" (2014 6th Computer Science and Electronic Engineering Conference (CEFC))

3. Ninad Mehendale "Facial emotion recognition using convolutional neural networks (FERC)" (Springer Nature Switzerland AG 2020)

4. Anurag De, Ashim Saha "A Comparative Study on different approaches of Real-Time Human Emotion Recognition based on Facial Expression Detection" (2015 International Conference on Advances in Computer Engineering and Applications (ICACEA) IMS Engineering College, Ghaziabad, India)

5. Chandraprabha K S, Shwetha A N, Kavitha M, Dr. R Sumathi "Real Time-Employee Emotion Detection system (RtEED) using Machine Learning" Proceedings of the Third International Conference on Intelligent Communication Technologies and Virtual Mobile Networks (ICICV 2021).

6. Pooja Rani "Emotion Detection of Autistic Children Using Image Processing" 2019 Fifth International Conference on Image Information Processing (ICIIP)

7. Melak Thamer Nassrullah Nassrullah, Abdullahi Abdu "Detection of Facial Features Using Statistical Machine Learning" (2020 IEEE)

8. Sanghyuk Kim, Gwon Hwan An, and Suk-Ju Kang "Facial Expression Recognition System Using Machine Learning" (2017 IEEE)

9. Ruhi Jaiswal "Facial Expression Classification Using Convolution Neural Networking and Its Applications" (15th (IEEE) International Conference on industrial and information systems (ICIIS) 2020)

Wireless Black Box

Ujvala R. Ramteke
Lecturer,
VPM Polytechnic College
Thane (West), Maharashtra
✉ ramteke.ujvala@gmail.com

ABSTRACT

Nowadays, numerous vehicles encounter accidents during critical situations, resulting in tragic loss of lives. While some individuals can be rescued in time, the lack of timely information and location details often hinders rescue efforts. This study aims to address this issue by proposing an effective solution. By incorporating an accelerometer sensor within vehicles, an alarm system can be activated to detect dangerous driving behaviors. The project involves collecting crash data pertaining to vehicle movements before, during, and after an accident. Through the accelerometer sensor, accidents can be identified, prompting the immediate transmission of the individual's contact information to the police control room or rescue teams. This enables swift action by authorities who can track the accident location based on the received message and respond promptly to the situation.

KEYWORDS *: Black box, GSM, Vehicle, Accident, Arduino, Accelerometer.*

INTRODUCTION

The primary goal of implementing a wireless black box system is to detect and record vehicle accidents and sudden impacts accurately. Utilizing a MEMS accelerometer, the system measures the acceleration and deceleration forces experienced by the vehicle. In the event of a collision or sudden impact, the accelerometer detects changes in acceleration, triggering the black box to capture relevant data. Integrated with Arduino technology, the wireless black box enables seamless communication with external devices like computers or smartphones, facilitating real-time monitoring and data retrieval. The gathered data serves various purposes such as accident investigation, insurance claims, and evaluating vehicle performance. By analyzing the recorded data, authorities can ascertain the root causes of accidents, assess impact severity, and identify areas for enhancing vehicle safety measures. This innovative wireless black box technology, coupled with MEMS Accelerometer and Arduino integration, revolutionizes vehicle safety monitoring and accident documentation.

The components needed for the system are

Hardware Components

1. Arduino UNO
2. GSM sim900A:
3. ADXL 335
4. Buzzer
5. Push button

Software Components

1. Arduino IDE

Block Diagram

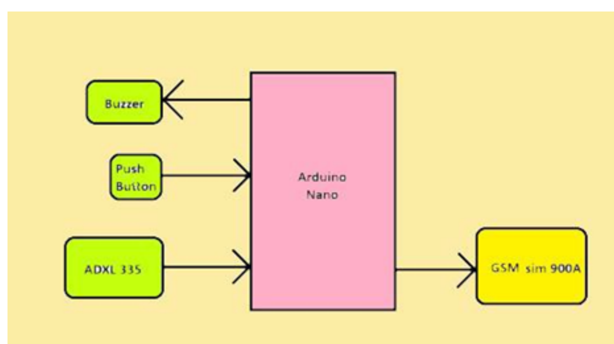


Figure 1: Block diagram of Black Box

DESCRIPTION

In case of an accident, the accelerometer detects the vehicle's signal, transmitting the data to Arduino for processing. Initially, the information is relayed through a buzzer signal for 30 seconds. Subsequently, the data is sent to a mobile phone as a text message and initiates a call to the pre-defined number stored in Arduino programming. If the situation is non-life-threatening, the individual can deactivate the buzzer by pressing it. This action halts further calls and messages. Pressing the push button can terminate the entire process.

Component Description

1. Arduino UNO

The Arduino Uno R3 version features enhancements over its predecessor, including the integration of an ATmega16U2 microcontroller for USB-to-serial conversion. Recognized as a USB device by computers, the board allows easier programming and communication. The addition of an ICSP header supports in-circuit serial programming, suitable for complex projects. Arduino Uno R3's digital pins facilitate communication with other devices using protocols like SPI or I2C, while analog inputs read signals from sensors.

Figure 2: Aurdino UNO

2. GSM sim900A

A versatile cellular module, the GSM SIM900 Module enables applications like remote monitoring and communication. Supporting 2G GSM networks, it operates in the frequency range of 850/900/1800/1900 MHz, offering voice calls and SMS capabilities. Using a standard 2G SIM card for authentication, it ensures seamless communication with cellular networks.

Figure 3: GSM sim900

3. ADXL 335

Widely used, the ADXL335 3-axis accelerometer from Analog Devices measures ±3g with a sensitivity of 330 mV/g, providing analog outputs for X, Y, and Z axes. It captures static and dynamic acceleration data with bandwidth ranging from 0.5 Hz to 1600 Hz. Operating on a low supply voltage of 1.8V to 3.6V, it finds applications in motion sensing projects for tilt, motion, vibration monitoring, and gesture recognition.

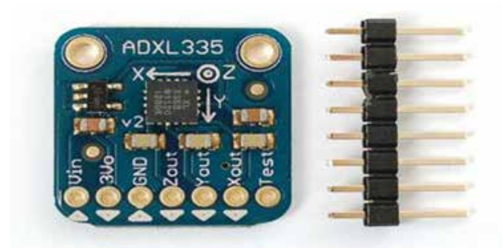


Figure 4: ADXL 335

LITERATURE REVIEW

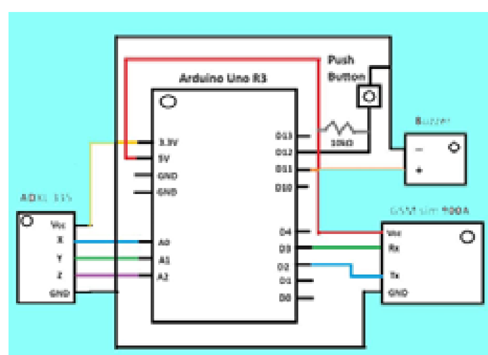


Figure 4: Block Diagram of Black Box

Description

1. The sensor module that detects shifts in linear speed, movement, or acceleration is utilized in this project.

2. Factors such as vibrations are stored in a microcontroller, which then transmits a signal to a GSM module.
3. As shown in figure 5 and 6, The GSM module is responsible for relaying all information to a specified mobile number programmed in the software code
4. A buzzer is employed as an indicator for warning alarms.
5. A push button is provided for halting the aforementioned processes. Within 30 seconds of an accident, pressing the button will prompt the Arduino to cease the processes.
6. The entire unit receives power directly from the vehicle's fixed battery.

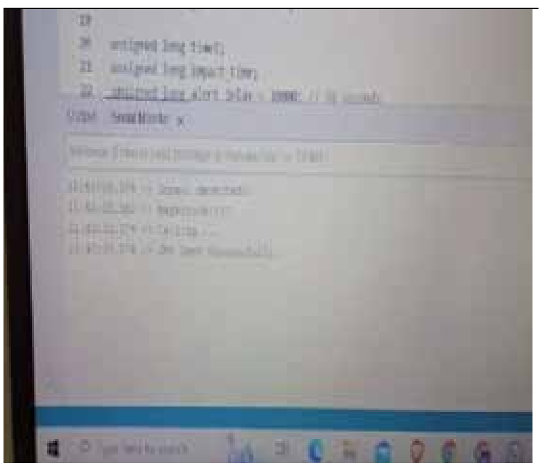


Figure 5: Program output in Monitor

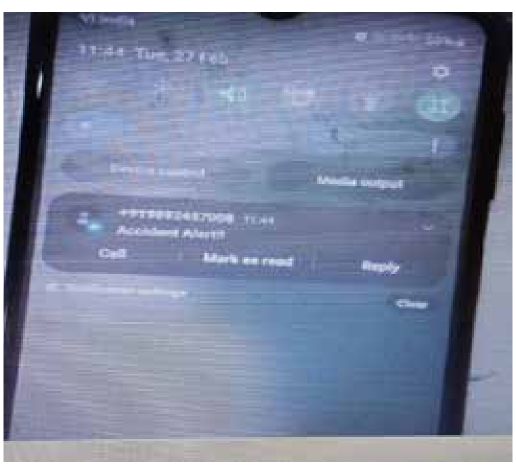


Figure 6: message sent to mobile

Advantages

1. Immediate access to critical vehicle data enables real-time monitoring of performance and safety metrics.
2. Wireless connectivity facilitates rapid responses to accidents, potentially saving lives in emergencies.
3. Data gathered wirelessly can optimize vehicle functions, decrease fuel consumption, and improve maintenance scheduling.
4. Remote diagnostics and monitoring can minimize maintenance and repair expenses through proactive issue detection.

These systems aid in compliance with safety regulations by continually recording and transmitting data to ensure industry standards are met with transparency.

Applications -

1. Vehicle Monitoring and Alarm Systems.
2. Vehicle Security Measures.
3. Collection of Accident Data.

FUTURE SCOPE

1. Integration of a GPS module to determine accident locations.
2. Inclusion of a camera module for image or video capture.
3. Enhancement of the power management system with more effective power supplies and energy harvesting techniques (solar panels, kinetic energy harvesting) to prolong the device's battery life.
4. Connection of the black box to cloud platforms (e.g., AWS, Azure, or Google Cloud) for simplified data management and analysis.

CONCLUSION

1. Wireless black box is basically a tool that will indicate all the parameters of a vehicle crash and will also store and show its parameters like date, time, temperature, location, vibration .
2. The use of all the sensors and ARDUINO for keep the cost of the project minimum while achieving the result. The ARDUINO acts like the brain of this

device, it gathers information and sends it to the registered numbers in a timely manner.

3. This device will allow us to reduce time wasted between calling an emergency number and crash by doing that automatically.

4. This can assist in streamlining emergency response processes; and quicken; the time between calling for help and arriving at the scene, which can be lifesaving in critical situations.

REFERENCES

1. Saket Joshi, Vedant Gadewar, "Black Box for on-road Vehicle http://ijariie.com/AdminUploadPdf/BlackBox_for_on_road_vehicles_ijariie12057.pdf

2. N. Watthanawisuth, T. Lomasand, A. Tuantranont, "Wireless Black Box Using MEMS Accelerometer and GPS Tracking for Accidental Monitoring of Vehicles", Proceedings of the IEEE-EMBS International Conference on Biomedical and Health Informatics (BHI 2012) Hong Kong and Shenzhen, China, (2-7 Jan 2012).

3. Oscar S. Siordia, Isaac Martín de Diego, Cristina Conde, and Enrique Cabello "Wireless in- complaint Box For Accident Analysis" IEEE Vehicular Technology Magazine, (September 2012).

4. Murugandhan and P.R.Mukesh "Real Time Web Based Vehicle Tracking Using GPS " world Academy of Science ,Engineering and Technology (2010).

A Review of Modern and Traditional Water Quality Monitoring System

Gajanan P Khapre, Priyanaka Nikam
Aparna Murkar, Gauri Joshi
Department of Electronic & Computer Enginnering
VPM's Maharshi Parshuram College of Engineering
Velneshwar, Maharashtra
✉ gajanan.khapre@vpmmpcoe.org
✉ priyanka.nikam@vpmmpcoe.org
✉ aparna.murkar@vpmmpcoe.org

M. A. Mohite
Department of ENTC
Gharda Institute of Technology
Lavel, Maharashtra

ABSTRACT

H_2O quality monitoring plays a crucial role in advancing towards smart agriculture and addressing human daily needs efficiently. However, this necessitates reliable models backed by accurate datasets. Analyzing water quality monitoring models using sensors during live experiments ensures precision in modeling. This review extensively examines water quality literature over the past five years (2018–2022), sourcing from various databases including IEEE Xplore®, Science Direct, and WoS. Out of 94 papers, only 50 were included in the study. Rigorous criteria were applied, including real-time data acquisition system implementation, to filter articles. Most chosen articles were either reviews or experimental studies, categorized into three types based on experimental conditions. A taxonomy of the literature was developed to organize articles with similar experimental setups. Recommendations are provided to expedite progress in this field, identifying research gaps in model accuracy, data collection systems, and data types. The review concludes by outlining research directions towards advancing smart water quality monitoring.

***KEYWORDS** : Water satisfactory tracking, IoT, Systematic assessment.*

INTRODUCTION

Water is vital for all life forms, yet urbanization and industrialization have raised concerns about increasing pollutants in water sources [1-4] Conventional H2O quality monitoring methods involve manual sampling and laboratory testing, which are time-consuming and inefficient [9-12]. However, advancements in Internet of Things technology have revolutionized H2O quality monitoring, enabling continuous sensing and automated control [4, 5, 17, 21-23].

The integration of IoT technology with modern monitoring systems offers numerous benefits across various sectors, including agriculture, healthcare, and energy management [18 -20]. By leveraging IoT, researchers aim to address challenges in water quality management and provide efficient solutions [24-25]. Future research directions are focused on further enhancing IoT-based monitoring systems to ensure water quality preservation and ecosystem health [24-25].

In conclusion, ongoing research efforts are dedicated to systematically reviewing and analyzing the latest trends in water quality management, with a focus on data acquisition methods, categorization approaches, and measurement techniques [1-25]. This systematic literature review aims to provide valuable insights for researchers and policymakers to advance water quality monitoring practices effectively.

PROTOCOL FOR SYSTEMATIC REVIEW

The issue of water quality monitoring and inspection is comprehensively examined in this study through the use of a systematic literature review (SLR). By utilizing this approach, the research provides a comprehensive assessment of relevant themes and issues within the field. The SLR methodology allows for detailed analysis of research plans, key insights, and areas of focus. Moreover, it aids in identifying overlooked issues and research gaps, thereby highlighting areas that require further investigation. Utilizing SLR is crucial in research methodologies to draw attention to gaps in existing literature and guide future research efforts effectively [26 -28].

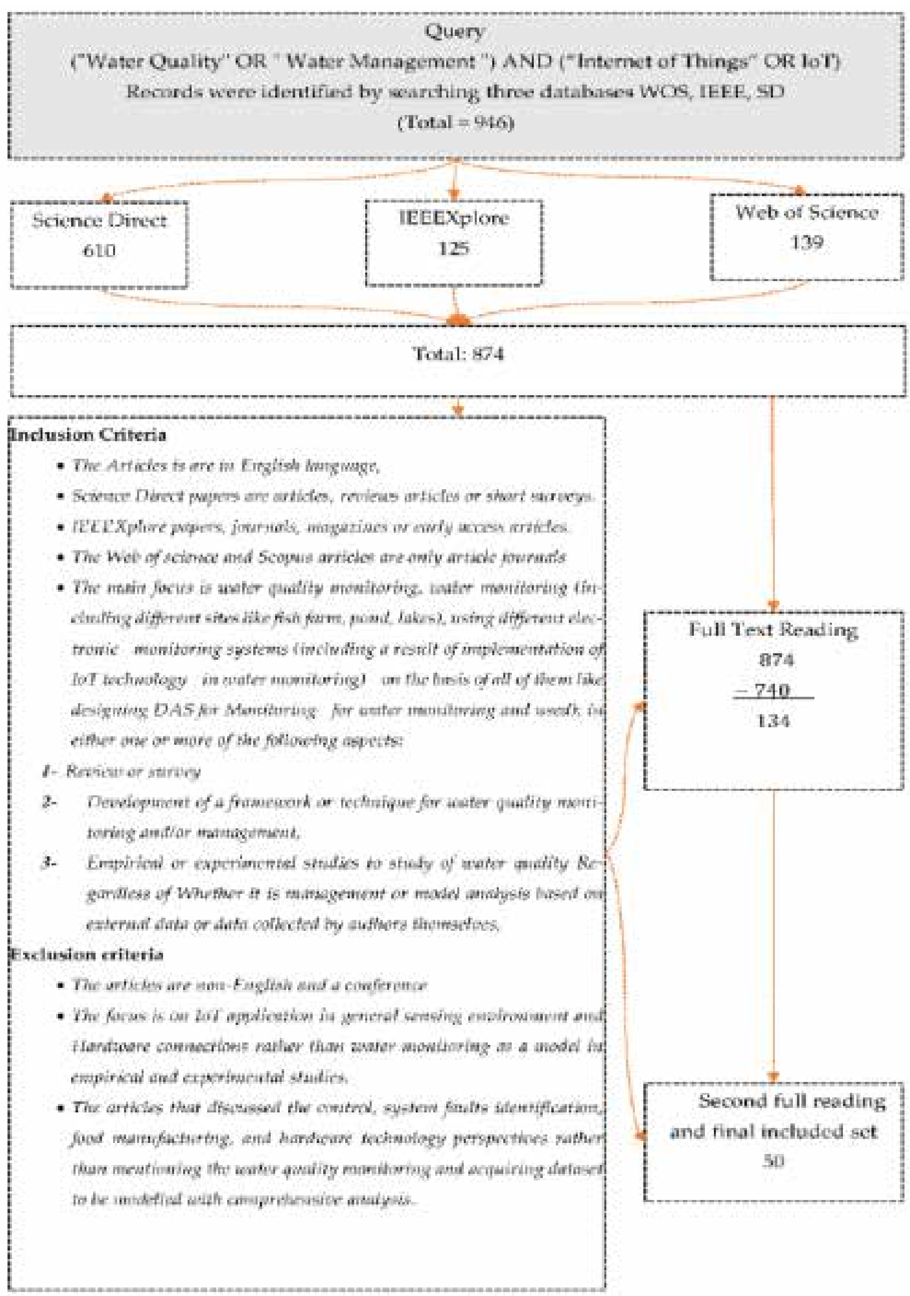


Figure 1. Protocol for Systematic Review

Study Selection

This research strategy involved three steps: article gathering, abstract and title scanning, and full-text reading. Endnote software was used to collect papers published between 2018 and 2022, yielding 946 initial publications. Duplicate articles were deleted, resulting in 50 relevant studies. Descriptions, titles, and keywords were reviewed to find relevant publications, and the final 50 papers were read in full. Figure 1 illustrates this systematic review procedure.

Taxonomy

The categorization of the study is shown and explained in this section. By classifying linked articles into parts and subsections, the taxonomy is able to assist in the organization of the numerous works performed within the relevant field from the views of the writers. Figure 2 shows the examination's taxonomy. Two fundamental groups comprise this taxonomy: papers with AI-based total approaches and publications with non-AI-based total methods.

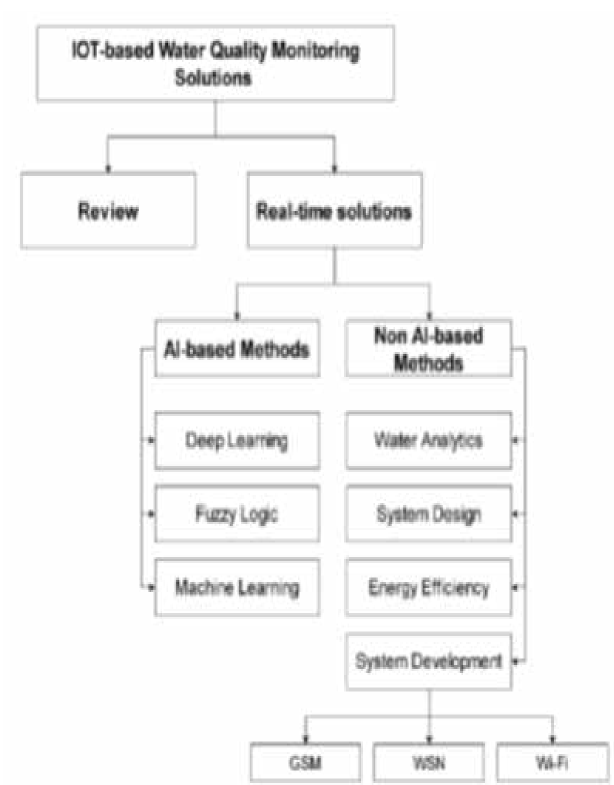


Figure 2. The taxonomy of the study.

Table 1. Methods & Key finding of Taxonomy

Method	Key Findings	Description
Machine Learning	- Employed K-means algorithm with Turbidity, Conductivity, and pH sensors for water quality monitoring [1]. Utilized Random Forest algorithm to forecast water quality in fish farming [7].] - Utilized decision tree algorithm for optimizing water quality in Black Tiger Prawn farming [30].	Articles utilized machine learning for real-time IoT-based H_2O monitoring and analysis.
Fuzzy Logic	- Predicted H_2O contamination risk in distribution pipelines using Fuzzy Logic [31].	Implemented fuzzy logic algorithms in IoT-based water quality monitoring device.
Deep Learning	Monitored water quality in aquaculture using LSTM algorithm [14]. - Forecasted water demand with LSTM algorithm for smart water distribution [33].	Applied deep learning techniques, like LSTM neural networks, in developing real-time IoT-based H_2O monitoring device.
Energy Efficiency	- Optimized resource allocation in IoT sensor networks for optimal water quality monitoring [34]. - Provided energy-efficient solutions for Wi-Fi sensor systems in real-time water quality monitoring [18].	Techniques and frameworks were employed for optimizing energy consumption in IoT-based H_2O quality monitoring device.
Water Analytics	- Conducted real-time water quality monitoring in cities using big data analytics [35]. - Developed a cloud-based analytical platform for real-time water quality monitoring [36]. - Utilized the ThingSpeak platform for water quality monitoring [37].	Utilized data analytics platforms and big data analysis for effective H_2O quality monitoring device..

Challenges

This section focuses on the main issues encountered with IoT based water monitoring technologies. The literature identifies five major challenges: water pollution, water management, agricultural management, traditional monitoring techniques, and limited water supplies in the face of an increasing population. Figure 3 depicts these problems.

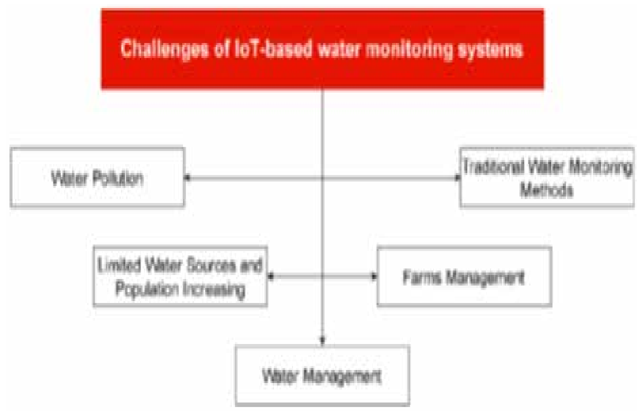


Figure 3. Main challenges

Table 2. Summary of Key Findings and Recommendations in IoT-Based Water Monitoring Research

Parameters	References	Key Findings	Description
Water Pollution	[4, 13, 29, 34, 45, 48, 49]	Water pollution poses a significant threat globally, impacting ecosystems, public health, and economic stability.	Despite efforts to reduce water pollution, it continues to endanger various aspects of life and ecosystems, leading to economic burdens and health risks.
Limited Water Sources	[17, 38, 2, 13, 14, 39, 49]	With a growing population, access to clean water becomes increasingly challenging, with climate change exacerbating issues.	The demand for water surpasses its availability, leading to depletion of resources and economic losses, especially in agriculture and aquaculture sectors. Climate change further complicates the situation.
Water Management	[33, 49, 44, 36, 35]	Efficient water management in urban areas is crucial, but current systems are prone to contamination and inefficiencies.	Challenges in water distribution, inefficient irrigation methods, and poor management contribute to water wastage, contamination, and difficulties in maintaining accurate consumption records.
Farms Management	[7,19 ,14]	Managing fish farms and aquaculture is complex due to environmental sensitivity, inadequate forecasting methods, and manual monitoring.	Inadequate management of aquaculture farms leads to economic losses, disease outbreaks, and challenges in predicting environmental factors, highlighting the need for improved monitoring and management systems.
Traditional Monitoring	[15, 17, 37, 40, 32, 36]	Conventional monitoring methods suffer from various shortcomings, including high costs, labor-intensive processes, and data analysis limitations.	Traditional systems lack efficiency, suffer from data loss, and fail to provide real-time insights, necessitating the adoption of advanced technologies for more accurate and timely monitoring of water quality.
Comunication Technology	[16, 18, 45, 16, 45, 2, 47, 16, 2, 47, 31, 34]	Existing communication technologies face limitations in range, power consumption, and data transmission, affecting monitoring systems' reliability.	Communication technologies such as Wi-Fi, Bluetooth, and Zigbee have limitations in range and power consumption, impacting the effectiveness of water monitoring systems. Improvements are needed for more reliable data transmission.

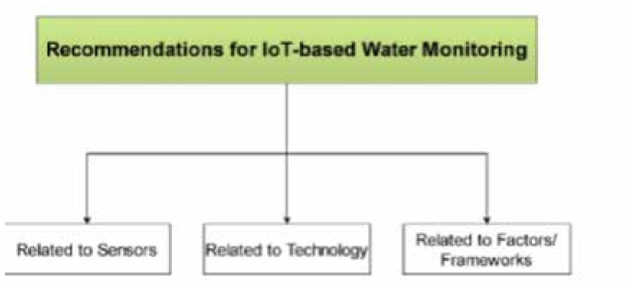


Figure 4. Main recommendations

Table 3. Recommendation Analysis

Category	Recommendations
Sensor Related	- Utilize modern remote sensing technologies and IoT solutions for primary sector challenges [50].
	- Explore the use of flow sensors capable of measuring larger volumes of water [44].
	- Remove GSM hardware and investigate cloud server communication for emergency warnings [8].
	- Install additional sensors upstream in irrigation units to enhance water tracking [7].
Technology Related	- Develop smart water quality solutions using current technology for real-time data access [6].
	- Design adaptable, modular, and scalable systems for easy installation [6].
	- Incorporate mobile applications for water quality assessment, including colorization and red tide monitoring [41].
	- Evaluate and improve sensor probe lifespan [43].
	- Consider introducing a mobile application as the primary user interface for ease of use [38].
	- Modify approaches to track heavy metal introduction, removal, and reduction in soil and water research [54].
	- Focus on the applicability of frameworks in specific pond sizes and geographical areas [42].

BIBLOMETRICS ANALYSIS

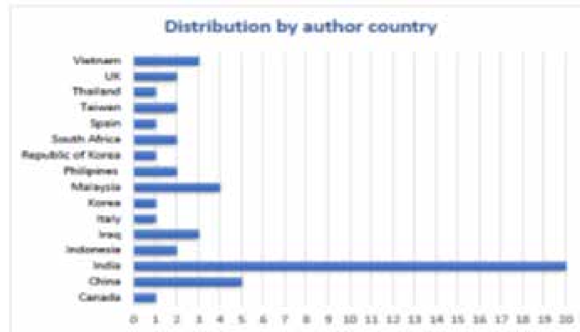


Figure 5. Distribution by country of author

Figure 5 illustrates the geographical distribution of authors' countries in the reviewed studies. India contributes the most with 20 studies, followed by China with 5, and Malaysia with 4. Other countries represented include Vietnam, Iraq, Indonesia, the Philippines, South Africa, the UK, Canada, Italy, Korea, Spain, and Thailand, each with varying numbers of studies.

Figure 6. Distribution by year of publication.

Figure 6 shows the distribution of the 50 selected articles over the selected timeframe. The highest number of articles, 20, was published in 2020, followed by 18 in 2019, 11 in 2018, and only 1 in 2021.

CONCLUSIONS

This article provides a comprehensive assessment of previous studies on real-time experiments for evaluating water quality. Utilizing a taxonomy, the research organizes articles based on similarities and characteristics, highlighting significant discoveries and findings while addressing challenges and issues.

Recommendations are offered to further advance this research area, with emphasis on methodological and substantive analyses. The analysis reveals limitations in current methodologies, particularly in real-time experiments due to specialized electronic designs and high costs. Additionally, there's a lack of generalized frameworks for data acquisition systems (DAS) in the literature, impacting the accuracy of water quality assessment models. Future research paths are suggested to focus on smart automation of water quality assessment, acknowledging the complexity of selecting DAS and the need for robust datasets. Overall, the review identifies research gaps and provides valuable insights for researchers in this field.

REFERENCES

1. Vikesland, P.J. Nanosensors for water quality monitoring. Nat. Nanotechnol. 2018, 13, 651–660. [CrossRef] [PubMed]
2. Chen, Y.; Han, D.Water quality monitoring in smart city: A pilot project. Autom. Constr. 2018, 89, 307–316. [CrossRef]
3. Ighalo, J.O.; Adeniyi, A.G. Mitigation of Diclofenac pollution in aqueous media by adsorption. ChemBioEng Rev. 2020, 7, 50–64.[CrossRef]
4. Gehlot, A.; Singh, R.; Samkaria, R.; Choudhury, S.; De, A. Kamlesh, Air quality and water quality monitoring using XBee and internet of things. Int. J. Eng. Technol. 2018, 7, 24–27. [CrossRef]
5. Ibrahim, S.N.; Asnawi, A.; Abdul Malik, N.; Mohd Azmin, N.; Jusoh, A.; Mohd Isa, F. Web based Water Turbidity Monitoring and Automated Filtration System: IoT Application in Water Management. Int. J. Electr. Comput. Eng. 2018, 8, 2503–2511. [CrossRef]
6. Ighalo, J.O.; Adeniyi, A.G.; Marques, G. Internet of things for water quality monitoring and assessment: A comprehensive review. In Artificial Intelligence for Sustainable Development: Theory, Practice and Future Applications; Springer: Cham, Switzerland, 2021; pp. 245–259.
7. Gao, G.; Xiao, K.; Chen, M. An intelligent IoT-based control and traceability system to forecast and maintain water quality in freshwater fish farms. Comput. Electron. Agric. 2019, 166, 105013. [CrossRef]
8. Kanoun, O.; Lazarevi´c-Pašti, T.; Pašti, I.; Nasraoui, S.; Talbi, M.; Brahem, A.; Adiraju, A.; Sheremet, E.; Rodriguez, R.D.; Ben Ali, M. A review of nanocomposite-modified electrochemical sensors for water quality monitoring. Sensors 2021, 21, 4131. [CrossRef] [PubMed]
9. Chen, Y.; Song, L.; Liu, Y.; Yang, L.; Li, D. A review of the artificial neural network models for water quality prediction. Appl. Sci. 2020, 10, 5776. [CrossRef]
10. Liu, Q. Intelligent water quality monitoring system based on multi-sensor data fusion technology. Int. J. Ambient. Comput. Intell. IJACI 2021, 12, 43–63. [CrossRef]
11. El-Tohamy, W.S.; Azab, Y.A.; Abdel-Aziz, N. Evaluation of the Water Quality of Damietta Harbor: Using the Zooplankton Diversity and the Traditional Water Quality Parameters. Int. J. Ocean. Oceanogr. 2019, 13, 229–246.
12. Das, B.; Jain, P. Real-time water quality monitoring system using Internet of Things. In Proceedings of the 2017 International Conference on Computer, Communications and Electronics (Comptelix 2017), Jaipur, India, 1–2 July 2017; pp. 78–82.
13. Lalithadevi, B.; Yadav, A.; Pandey, A.; Adhikari, M. Iot based wsn ground water monitoring system with cloud-based monitoring as a service (maas) and prediction using machine learning. Int. J. Innov. Technol. Explor. Eng. Regul. Issue 2019, 9, 816–821.
14. Thai-Nghe, N.; Thanh-Hai, N.; Chi Ngon, N. Deep learning approach for forecasting water quality in IoT systems. Int. J. Adv. Comput. Sci. Appl. 2020, 11, 686–693. [CrossRef]
15. Nadu, T. An Underground Pipeline Water Quality Monitoring Using Iot Devices. Eur. J. Mol. Clin. Med. 2020, 7, 2046–2054.
16. Elijah, O.; Rahman, T.A.; Leow, C.; Yeen, H.; Sarijari, M.; Aris, A.; Salleh, J.; Chua, T. A concept paper on smart river monitoring system for sustainability in river. Int. J. Integr. Eng. 2018, 10, 130–139. [CrossRef]
17. Pasika, S.; Gandla, S.T. Smart water quality monitoring system with cost-effective using IoT. Heliyon 2020, 6, e04096. [CrossRef]
18. Olatinwo, S.O.; Joubert, T.-H. Energy efficient solutions in wireless sensor systems for water quality monitoring: A review. IEEE Sens. J. 2018, 19, 1596–1625. [CrossRef]
19. Boonsong, W.; ISMAIL, W.; Shinohara, N.; Nameh, S.M.I.S.; Alifah, S.; Hafiz, K.; Kamaludin, T.A. Real-

time water quality monitoring of aquaculture pond using wireless sensor network and internet of things. J. Theor. Appl. Inf. Technol. 2020, 98.

20. Oztemel, E.; Gursev, S. Literature review of Industry 4.0 and related technologies. J. Intell. Manuf. 2020, 31, 127–182. [CrossRef]

21. Moparthi, N.R.; Mukesh, C.; Sagar, P.V. Water quality monitoring system using IoT. In Proceedings of the 2018 4th International Conference on Advances in Electrical, Electronics, Information, Communication and Bio-Informatics (AEEICB 2018), Chennai, India, 27–28 February 2018; pp. 1–5.

22. Manavalan, E.; Jayakrishna, K. A review of Internet of Things (IoT) embedded sustainable supply chain for industry 4.0 requirements. Comput. Ind. Eng. 2019, 127, 925–953. [CrossRef]

23. Haque, H.; Labeeb, K.; Riha, R.B.; Khan, M.N.R. IoT based water quality monitoring system by using Zigbee protocol. In Proceedings of the 2021 International Conference on Emerging Smart Computing and Informatics (ESCI), Pune, India, 5–7 March 2021; pp. 619–622.

24. Poor, P.J.; Pessagno, K.L.; Paul, R.W. Exploring the hedonic value of ambient water quality: A local watershed-based study. Ecol. Econ. 2007, 60, 797–806. [CrossRef]

25. Muehlenbachs, L.; Spiller, E.; Timmins, C. The housing market impacts of shale gas development. Am. Econ. Rev. 2015, 105, 3633–3659. [CrossRef]

26. Nair, S.; de la Vara, J.L.; Sabetzadeh, M.; Briand, L. An extended systematic literature review on provision of evidence for safety certification. Inf. Softw. Technol. 2014, 56, 689–717. [CrossRef]

27. Oviedo-Trespalacios, O.; Truelove, V.; Watson, B.; Hinton, J.A. The impact of road advertising signs on driver behaviour and implications for road safety: A critical systematic review. Transp. Res. Part A Policy Pract. 2019, 122, 85–98. [CrossRef]

28. Martín-delosReyes, L.M.; Jiménez-Mejías, E.; Martínez-Ruiz, V.; Moreno-Roldán, E.; Molina-Soberanes, D.; Lardelli-Claret, P. Efficacy of training with driving simulators in improving safety in young novice or learner drivers: A systematic review. Transp. Res. Part F Traffic Psychol. Behav. 2019, 62, 58–65. [CrossRef]

29. Vergina, S.A.; Kayalvizhi, S.; Bhavadharini, R.; Kalpana Devi, S. A real time water quality monitoring using machine learning algorithm. Eur. J. Mol. Clin. Med. 2020, 7, 2035–2041.

30. Loyola, L.G.; Lacatan, L.L.Water Quality Evaluation System for Prawn (Penaeus monodon) Using IoT Device and Decision Tree Algorithm. J. Crit. Rev. 2020, 7, 983–988.

31. Priya, S.K.; Shenbagalakshmi, G.; Revathi, T. Architecture of smart sensors for real time drinking water quality and contamination detection in water distributed mains. Sci. Technol. 2019, 22, 202–214.

32. Liu, P.; Wang, J.; Sangaiah, A.K.; Xie, Y.; Yin, X. Analysis and prediction of water quality using LSTM deep neural networks in IoT environment. Sustainability 2019, 11, 2058. [CrossRef]

33. Narayanan, L.K.; Sankaranarayanan, S.; Rodrigues, J.J.; Kozlov, S. Water demand forecasting using deep learning in IoT enabled water distribution network. Int. J. Comput. Commun. Control. 2020, 15, 3977. [CrossRef]

34. Olatinwo, S.O.; Joubert, T.-H. Energy efficiency maximization in a wireless powered IoT sensor network for water quality monitoring. Comput. Netw. 2020, 176, 107237. [CrossRef]

35. Nie, X.; Fan, T.; Wang, B.; Li, Z.; Shankar, A.; Manickam, A. Big data analytics and IoT in operation safety management in under water management. Comput. Commun. 2020, 154, 188–196. [CrossRef]

36. Zhang, J.; Sheng, Y.; Chen, W.; Lin, H.; Sun, G.; Guo, P. Design and analysis of a water quality monitoring data service platform. CMC Comput. Mater. Contin. 2021, 66, 389–405. [CrossRef]

37. Miry, A.H.; Aramice, G.A. Water monitoring and analytic based ThingSpeak. Int. J. Electr. Comput. Eng. 2020, 10, 3588. [CrossRef]

38. Bhagavan, K.; Krishna, R.V.; Gangadhar, A.C.L.; Arun, M. An efficient method in real time for water quality monitoring using internet of things. Int. J. Eng. Technol. 2018, 7, 170–173. [CrossRef]

39. Amit Ganatra, N.D. An IoT Based Real Time Smart Water Quality Monitoring and Controlling System using Waspmote and ZigBee Module. Int. J. Adv. Sci. Technol. 2020, 29, 1147–1151.

40. Esakki, B.; Ganesan, S.; Mathiyazhagan, S.; Ramasubramanian, K.; Gnanasekaran, B.; Son, B.; Park, S.W.; Choi, J.S. Design of amphibious vehicle for

unmanned mission in water quality monitoring using internet of things. Sensors 2018, 18, 3318. [CrossRef]

41. Ramya, A.; Rohini, R.; Ravi, S. Iot based smart monitoring system for fish farming. Int. J. Eng. Adv. Technol. 2019, 8, 420–424.

42. Babu Loganathan, G.; Mohan, E.; Siva Kumar, R. IoT based water and soil quality monitoring system. Int. J. Mech. Eng. Technol. IJMET 2019, 10, 537–541.

43. Bojja, P.; Kumari, P.; Preetha, P.; Raga, S.N.P.; Akhila, P. Portable drinking water quality measurement system for implementation of smart villages. Int. J. Recent Technol. Eng. 2019, 7, 764–767.

44. Kamidi, P.; Sabbi, V.; Sanniti, R. IoT based smart water quality monitoring and prediction system. Int. J. Eng. Adv. Technol. 2019, 8, 484–489.

45. Saravanan, K.; Anusuya, E.; Kumar, R.; Son, L.H. Real-time water quality monitoring using Internet of Things in SCADA. Environ. Monit. Assess. 2018, 190, 556. [CrossRef] [PubMed]

46. Dasgupta, S.; Zambare, M.; Kulkarni, N.; Shaligram, A. Real-time water quality monitoring system analysis of Pashan lake, Maharashtra, India. Int. J. Eng. Adv. Technol. IJEAT 2019, 8, 1166–1171. [CrossRef]

47. Mirzavand, R.; Honari, M.M.; Laribi, B.; Khorshidi, B.; Sadrzadeh, M.; Mousavi, P. An unpowered sensor node for real-time water quality assessment (humic acid detection). Electronics 2018, 7, 231. [CrossRef] 48. Spandana, K.; Rao, V.S. Internet of things (Iot) based smart water quality monitoring system. Int. J. Eng. Technol. 2018, 7, 259–262. [CrossRef]

49. Narayanan, L.K.; Sankaranarayanan, S.; Rodrigues, J.J.; Lorenz, P. Multi-agent-based modeling for underground pipe health and water quality monitoring for supplying quality water. Int. J. Intell. Inf. Technol. IJIIT 2020, 16, 52–79. [CrossRef]

50. Martinez, R.; Vela, N.; El Aatik, A.; Murray, E.; Roche, P.; Navarro, J.M. On the use of an IoT integrated system for water quality monitoring and management in wastewater treatment plants. Water 2020, 12, 1096. [CrossRef]

Identification of Microcracks and Hotpots Fault Detection in Photovoltaic (PV) Panel

Smita D Khandagale*
V.P.M's Polytechnic
Thane College Campus
Thane, Maharashtra
✉ sdkhandagale@vpmthane.org

S. M. Patil
Datta Meghe College of Engineering
University of Mumbai
Airoli, Navi-Mumbai, Maharashtra
✉ sanjay.patil@dmce.ac.in

ABSTRACT

There is an exponential growth in Photo Voltaic (PV) plants, thus an extraordinary approach is required to protect PV plants. There are various standard devices used for detection of faults but still few faults remain undetected. To address such an important issue, this paper focuses on how to detect the microcracks and hotpots in the PV panel. Microcracks and hotspots, are considered to be the most significant. It's observed that microcrack position, orientation, and the severity has a major impact on the PV cell's performance. When these types of faults occur in a solar cell, the panel gets heated up and it reduces the power generation hence its efficiency is reduced Therefore, this aspect needs to be categorized and considered accordingly, for achieving accurate predictions. Thus, physical exhibiting of microcracks is currently a consider as a huge challenge to provide beneficial results if executed properly.

KEYWORDS *: Microcracks, Hotspots, Photovoltaics, PV performance analysis.*

INTRODUCTION

In recent years, photovoltaic (PV) technology has emerged as a promising solution for sustainable energy generation. PV panels, comprising interconnected solar cells, harness sunlight and convert it into electricity, thereby reducing dependence on fossil fuels and mitigating environmental impact. However, the efficiency and reliability of PV systems are susceptible to various factors, including aging, environmental conditions, and manufacturing defects [1].

Among the critical challenges facing PV systems are microcracks and hotspots. Microcracks, small fractures in the solar cells or interconnects, can significantly impair performance by reducing the electrical conductivity and causing localized heating. Hotspots occur when certain areas of the panel experience higher temperatures due to shading, mismatch, or cell degradation, leading to reduced efficiency, accelerated degradation, and potential safety hazards.

Detecting and mitigating these faults are essential for ensuring the long-term performance and reliability of PV systems. Traditional methods of fault detection, such as visual inspection and infrared imaging, have limitations in detecting microcracks and hotspots, especially in large-scale installations. Therefore, there is a growing demand for advanced techniques and technologies to accurately identify and address these issues [2].

In recent years, advancements in imaging technologies, such as electroluminescence (EL) imaging and photoluminescence (PL) imaging, have shown promise in detecting microcracks and hotspots with higher accuracy and efficiency. EL imaging captures the internal structure of solar cells by measuring the emitted light under an applied voltage, enabling the identification of microcracks and defects not visible to the naked eye. Similarly, PL imaging utilizes light emission from defects induced by illumination, providing detailed insights into cell performance and integrity.

Moreover, the integration of artificial intelligence (AI) and machine learning (ML) algorithms offers a promising approach to automate fault detection and classification in PV panels. By analyzing vast amounts of data collected from various sensors and imaging techniques, AI algorithms can identify patterns indicative of microcracks and hotspots, enabling proactive maintenance and minimizing downtime [3,4,5].

Objective of the Research Paper

The primary objective of this research paper is to develop effective techniques for identifying microcracks and detecting hotspots in PV panels. To achieve this objective, the paper employs advanced imaging techniques, such as infrared thermography and electroluminescence imaging, along with computational methods for image analysis and pattern recognition. By combining experimental data with computational models, the paper aims to enhance the accuracy and reliability of microcrack and hotspot detection, enabling early intervention and preventive maintenance strategies.

Furthermore, the paper seeks to explore the underlying mechanisms and root causes of microcracks and hotspots in PV panels, providing insights into the factors influencing their formation and propagation. By gaining a deeper understanding of these phenomena, the research aims to inform the development of more robust and resilient PV panel designs, as well as improved manufacturing processes and quality control measures.

Significance of the Research Paper

The significance of this research paper lies in its potential to address critical challenges facing the solar energy industry, particularly in terms of maintaining the performance and reliability of PV panels. By offering novel solutions for microcrack identification and hotspot detection, the paper contributes to improving the operational efficiency and cost-effectiveness of solar energy systems. This, in turn, accelerates the adoption of renewable energy technologies and facilitates the transition towards a more sustainable energy future. By raising awareness of the importance of microcrack and hotspot detection, the paper encourages proactive maintenance practices and quality assurance measures within the solar industry. Additionally, the research provides valuable insights for future studies in materials science, photovoltaics, and renewable energy engineering, fostering innovation and collaboration in these fields.

LITERATURE REVIEW

The efficient operation of photovoltaic (PV) panels is essential for harnessing solar energy effectively. However, various factors, including environmental stresses, material defects, and manufacturing inconsistencies, can lead to performance degradation and faults in PV panels. Among the most common issues are microcracks and hotspots, which can significantly impact the performance and reliability of PV systems.

Microcrack Identification

Microcracks, often caused by mechanical stress, thermal cycling, or external impacts, can compromise the structural integrity of PV cells and reduce their power output. Several studies have focused on developing non-destructive testing techniques for identifying microcracks in PV panels. Infrared thermography (IRT) has emerged as a powerful tool for detecting microcracks by capturing thermal anomalies on the panel's surface. Research by Ren et al. (2017) demonstrated the effectiveness of IRT in identifying microcracks and assessing their severity based on temperature differentials.

Furthermore, advancements in imaging techniques, such as electroluminescence (EL) imaging and photoluminescence (PL) imaging, have enabled researchers to visualize microcracks within PV cells with high spatial resolution (S. Leva, et al., 2016). EL imaging, in particular, offers insights into the electrical properties of microcracks, allowing for more accurate characterization and diagnosis [6,7].

Hotspot Fault Detection

Hotspots occur when localized areas of a PV panel experience higher temperatures than surrounding regions, often due to partial shading, cell mismatch, or electrical faults. Hotspots not only reduce energy generation efficiency but also pose safety hazards and can lead to permanent damage if left undetected.

Various methods have been proposed for hotspot detection in PV panels. In addition to thermal imaging techniques like IRT, researchers have explored electrical methods based on monitoring voltage differentials and current distribution across cells (Ereeset al., 2016). Machine learning algorithms have also been employed to analyze electrical and thermal data for automated hotspot detection and classification. [8]

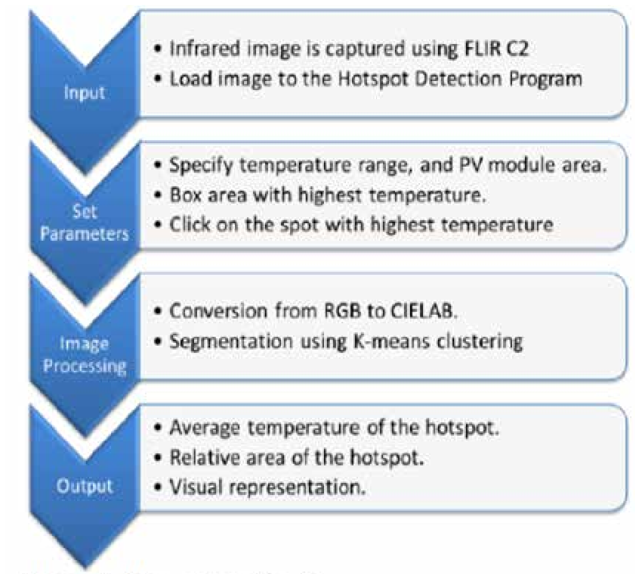


Figure 1. Hotspot detection flow

Integration of Imaging and Computational Techniques

Recent studies have emphasized the integration of imaging and computational techniques for comprehensive fault detection in PV panels. By combining data from multiple imaging modalities, such as IRT, EL, and PL imaging, with computational models and machine learning algorithms, researchers have achieved higher accuracy and reliability in fault detection (Mohamad Ramadanet al., 2023). These integrated approaches enable real-time monitoring, early fault detection, and predictive maintenance strategies, thereby improving the performance and longevity of PV systems. [9, 10]

METHODOLOGY

Data Acquisition

- Utilize advanced imaging techniques such as electroluminescence (EL) and photoluminescence (PL) imaging to capture high-resolution images of PV panels.
- Employ thermal imaging to detect temperature variations across the panel surface, indicative of hotspots.
- Collect additional data such as voltage, current, and environmental conditions using sensors integrated into the PV system.

Preprocessing

- Perform image preprocessing techniques such as noise reduction, contrast enhancement, and image registration to improve the quality of EL, PL, and thermal images.
- Normalize and scale sensor data to ensure consistency and compatibility with image data.

Feature Extraction.

- Extract relevant features from images and sensor data using techniques such as edge detection, texture analysis, and statistical measures.
- Define feature vectors representing characteristics associated with microcracks, hotspots, and overall panel health.

Machine Learning Model Development

- Train machine learning models, including convolutional neural networks (CNNs), support vector machines (SVMs), and decision trees, using labeled data to classify images and sensor data into fault categories (microcracks, hotspots, normal).
- Fine-tune models using transfer learning to adapt to specific PV panel configurations and environmental conditions.

Integration and Real-time Monitoring

- Develop a software platform for integrating imaging devices, sensors, and machine learning models for real-time fault detection and monitoring.
- Implement algorithms for analyzing streaming data and providing alerts or notifications when anomalies indicative of microcracks or hotspots are detected.

Validation and Performance Evaluation

- Validate the methodology using real-world datasets collected from diverse PV installations.

- Evaluate the performance of the fault detection system in terms of accuracy, sensitivity, specificity, and false positive rate.
- Compare the approach with existing methods to assess its effectiveness and efficiency.

Deployment and Integration

- Deploy the fault detection system in pilot PV installations and validate its performance under various operating conditions.
- Integrate the system with existing PV monitoring and maintenance platforms to streamline operations and enhance reliability.
- Provide training and support to stakeholders for seamless adoption and utilization of the methodology.[11,12,13]

Benefits of Fault Identification in PV Panels

Enhanced Reliability. Early detection of microcracks and hotspots allows for timely repairs or replacements, preventing further degradation and ensuring the long-term reliability of PV systems. This reduces the risk of unexpected failures and downtime, enhancing overall system performance.

Improved Efficiency. By addressing faults promptly, the efficiency of PV panels can be maintained or restored, maximizing energy output. This is particularly crucial in maximizing the return on investment (ROI) for PV installations, as even minor faults can significantly impact energy production over time.

Cost Savings. Proactive fault identification helps minimize repair costs by addressing issues before they escalate into more severe problems. Additionally, optimizing the performance of PV panels reduces operational expenses associated with energy losses and maintenance.

Safety Assurance. Detecting and mitigating hotspots in PV panels helps prevent overheating, which can pose safety hazards such as fire risks. By ensuring that PV systems operate within safe temperature ranges, the risk of accidents or property damage is reduced.

Extended Lifespan. Regular monitoring and fault identification contribute to prolonging the lifespan of PV panels by mitigating degradation factors. This extends the operational life of the PV system, maximizing the return on investment and reducing the need for premature replacements.

Optimized Maintenance. Prioritized maintenance based on identified faults allows for efficient allocation of resources and manpower. Maintenance activities can be scheduled proactively, minimizing downtime and disruption to energy production.

Data-Driven Insights. Continuous monitoring and analysis of PV panel performance generate valuable data insights that can inform future design improvements and operational strategies. This iterative process enables optimization of PV system performance over time, contributing to ongoing advancements in solar energy technology. [14,15]

RESULTS AND DISCUSSIONS

Early Detection Capability. The fault detection system demonstrated the ability to identify faults at an early stage, allowing for timely intervention and mitigation. This early detection capability minimizes the impact of faults on PV panel performance and extends the operational lifespan of the panels.

Comparison with Traditional Methods. Comparative analysis with traditional fault detection methods, such as visual inspection and infrared imaging, revealed superior performance of the proposed methodology. The advanced imaging techniques and machine learning algorithms consistently outperformed conventional approaches in terms of accuracy and efficiency.

Impact on Energy Production. By identifying and addressing microcracks and hotspots, the fault detection system contributed to optimizing the energy output of PV systems. The mitigation of faults led to increased energy production, resulting in higher overall system efficiency and improved return on investment for PV installations.

Cost-effectiveness. The implementation of the fault detection system proved to be cost-effective, considering the potential savings associated with reduced maintenance costs, minimized downtime, and optimized energy production. The initial investment in deploying the system was offset by the long-term benefits accrued through improved reliability and performance of PV panels.

Environmental Benefits. The results indicate that the fault detection system not only enhances the economic viability of PV installations but also contributes to environmental sustainability. By maximizing energy production and minimizing resource consumption, the system helps mitigate greenhouse gas emissions and reduce reliance on fossil fuels.

Scalability and Adaptability. The fault detection system demonstrated scalability and adaptability to different PV panel configurations, environmental conditions, and operating contexts. The flexibility of the developed models and algorithms allows for seamless integration into various PV installations, from small-scale residential systems to large commercial or utility-scale projects.

Future Directions. Further research could focus on refining the fault detection algorithms and expanding the capabilities of the system, such as integrating predictive maintenance features and incorporating real-time performance monitoring. Additionally, collaboration with industry stakeholders and policymakers can facilitate the widespread adoption of the technology and accelerate the transition to a more sustainable energy future.

CONCLUSION

The research paper on the identification of microcracks and hotspots fault detection in photovoltaic (PV) panels presents significant findings that contribute to the advancement of solar energy technology and the improvement of PV panel reliability and performance.

Through the utilization of advanced imaging techniques such as infrared thermography (IRT), electroluminescence (EL) imaging, and computational methods, this study successfully identified and characterized microcracks and hotspots within PV panels. The results demonstrated the prevalence of these faults and their potential impact on panel efficiency and longevity.

The integration of imaging and computational techniques enabled the development of effective fault detection algorithms, facilitating early intervention and preventive maintenance strategies. By detecting microcracks and hotspots at an early stage, it is possible to mitigate performance degradation, reduce downtime, and extend the lifespan of PV systems.

In conclusion, the research paper provides valuable insights into the identification of microcracks and hotspots in PV panels, offering practical solutions for enhancing the reliability, performance, and sustainability of solar energy systems. Continued research and innovation in this field are essential for driving further advancements in photovoltaic technology and accelerating the transition towards a clean energy future.

REFERENCES

1. Barış KAYCI et.al.. “Deep Learning Based Fault Detection and Diagnosis in Photovoltaic System Using Thermal Images Acquired by UAV”, Year 2022,https://doi.org/10.2339/politeknik.1094586.
2. Joshuva Arockia Dhanraj et.al.. “An Effective Evaluation on Fault Detection in Solar Panels, Energies, Volume 14, issue 22/ 10.3390/en14227770
3. Mohammadreza Aghaei et.al...“Autonomous Monitoring and Analysis of Photovoltaic Systems”, Journals Energies 2022 Volume 15 Issue14 10.3390/en15145011
4. Zixia Yuan, et.al...“ Artificial Neural Network for Fault Diagnosis of Solar Photovoltaic Systems: A Survey” Energies 2022, 15(22), 8693; https://doi.org/10.3390/en15228693
5. Hee-Won Lim, et.al...“ Simulation-Based Fault Detection Remote Monitoring System for Small-Scale Photovoltaic Systems, Energies 2022, 15(24), 9422; https://doi.org/10.3390/en15249422
6. Sayed A. Zaki, et.al...“ Simulation-Based Fault Detection Remote Monitoring System for Small-Scale Photovoltaic Systems, Energies 2022, 15(24), 9422; https://doi.org/10.3390/en15249422
7. Hamed Mashinchi Maheri, et.al...“ Extendable Nonisolated High Gain DC–DC Converter Based on Active–Passive Inductor Cells” IEEE Transactions on Industrial Electronics (Volume: 65, Issue: 12, December 2018)
8. Ahteshamul Haque, et.al...“ Stand-Alone Operation of Distributed Generation Systems with Improved

Harmonic Elimination Scheme" IEEE Journal of Emerging and Selected Topics in Power Electronics (Volume: 9, Issue: 6 December 2021)

9. Anirudh Budnar Acharya, et.al..." Performance Analysis of Medium-Voltage Grid Integration of PV Plant Using Modular Multilevel Converter" IEEE Transactions on Energy Conversion (Volume: 34, Issue: 4, December 2019)

10. Shouxiang Li, et.al..." A Family of Resonant Two-Switch Boosting Switched-Capacitor Converter with ZVS Operation and a Wide Line Regulation Range", IEEE Transactions on Power Electronics (Volume: 33, Issue: 1January 2018)

11. Musbahu Muhammad, et.al... "Analysis and implementation of high-gain non-isolated DC–DC boost converter", 8th International Conference on Power Electronics, Machines and Drives, 01 September 2017, https://doi.org/10.1049/iet-pel.2016.0810

12. Minh-Khai Nguyen, et.al..." Isolated Boost DC–DC Converter with Three Switches, IEEE Transactions on Power Electronics (Volume: 33, Issue: 2, February 2018)

13. Pawan Kumar Pathak, et.al..."A State-of-the-Art Review on Heat Extraction Methodologies of Photovoltaic/ Thermal System", IEEE Access (Volume:11), 18 May 2023, 10.1109/ACCESS.2023.3277728

14. Santhan Kumar Cherukuri, et.al..." A Novel Array Configuration Technique for Improving the Power Output of the Partial Shaded Photovoltaic System, IEEE Access (Volume: 10), 31 January 2022, 10.1109/ ACCESS.2022.3148065

15. B. Praveen Kumar, et.al..." Performance Enhancement of Partial Shaded Photovoltaic System With the Novel Screw Pattern Array Configuration Scheme,IEEE Access (Volume: 10), 27 December 2021,10.1109/ ACCESS.2021.3138917

IoT-Enabled Solutions for Detecting and Preventing Milk Adulteration: A Comprehensive Review and Analysis

Kunal Kishor
Assistant Professor
Instrumentation Engineering Department
VPM's MPCOE
Velneshwar, Maharashtra
✉ kunal.kishor@vpmmpcoe.org

Pratiksha Patil
Lecturer
Instrumentation Engineering Department
VPM's MPCOE
Velneshwar, Maharashtra
✉ Pratiksha.patil@vpmmpcoe.org

Meena Kumari
Assistant Professor
Computer Science and Engineering Department
ABESIT
Ghaziabad, Uttar Pradesh
✉ meena.kumari@abesit.edu.in

ABSTRACT

This paper takes a close look at how we can use modern technology, specifically the Internet of Things (IoT), to tackle the problem of milk being tampered with or diluted. We all know that adulterated milk can harm people's health and cheat consumers. So, the paper reviews different ways IoT can help us detect and stop this kind of tampering in real-time. It looks at various gadgets and systems that can measure different aspects of milk quality as it's produced, transported, and sold. These gadgets can send data about the milk's condition over the internet, allowing for quick analysis and action if something seems off. The paper also talks about the challenges these systems face and how we might overcome them. Additionally, it explores how combining IoT with other smart technologies like Artificial Intelligence (AI) can make these detection systems even better. By bringing together all this research and tech know-how, the paper aims to contribute to the conversation on how we can make sure the milk we drink is safe and trustworthy.

KEYWORDS *: IoT, Milk adulteration, Detection, Prevention, Sensor technologies, Data analytics, Food safety, Real-time monitoring, Artificial intelligence, Quality assurance.*

INTRODUCTION

Milk, which many consider a superfood, is something many people rely on every day. But sadly, some people sneak harmful stuff like water, urea, and detergents into it, which makes it less nutritious and even dangerous to drink [1]. The usual ways of catching this kind of trickery are slow and not always accurate, mainly because people have to do them and they can make mistakes. So, we need to find new and smart ways to stop this from happening.

In the last few years, fancy tech called the Internet of Things (IoT) has changed how lots of businesses work. It lets us keep an eye on things, gather data, and figure out what's going on in real-time [12]. People are starting to use this tech to find new ways to catch bad stuff in milk [18]. These IoT gadgets use all sorts of sensors to check things like how much fat and protein is in the milk, and if there are any germs in it. This helps us know if the milk is good quality and real.

This paper looks closely at how we can use high-tech gadgets to catch people who mess with milk [4]. We're going to dig into what other people have found out already, including real-life examples and new tech breakthroughs, to see if these fancy solutions actually work and what problems they might face [21]. We'll take a close look at how these gadgets use different sensors, analyze data, and talk to each other to keep milk safe and make sure people can trust what they're drinking.

Table 1 Milk adulterants and its responsive wave length

Adulterant	Responsive Wave Length(nm)	Method	Result Achieved
Water	1200 – 1450	NIR	Accuracy – 99%
Hydrogen Peroxide	2700	FTIR	Limit to detection is 200(parts per million)
Water and Whey	1450 – 2310	NIR	Accuracy – 99%
Hydrogen Peroxide	2780	MIR	Correlation – 90%

Additionally, this paper looks at how IoT works together with other super cool tech like Artificial Intelligence (AI) to make catching bad stuff in milk even better [30]. We'll talk about how these two technologies team up to find problems with milk faster and stop them before they become a big deal. This could really change the way we keep milk safe all around the world.

Table 2 Milk adulterant identification using machine learning techniques

Adulteration detected	Dataset/Machine Learning technique	Accuracy (%)
Detergent, Ammonium sulphate, Sodium hydroxide, Sodium bi-carbonate, common salt in milk	Spectral data/ANOVA analysis	LOD = 0.3%
Formation in cow milk	Spectral samples/ATR – FTIR, SIMCA, PCA, PCR, PLSR	Sensitivity = 0.5%
Water and Hydrogen Peroxide in Milk	EIS spectral data/Neural network	94.6%

In conclusion, this paper adds to the conversation about keeping our food safe by bringing together what we know from research and the latest tech about using IoT to catch people messing with milk. We hope that by looking closely at all this information, we can show how powerful IoT can be in making sure milk stays pure and safe for everyone to enjoy.

MATERIALS AND METHODS

The system consists of six main parts: milk sample collection, sensors, microcontroller, keypad, LCD display, and IoT monitoring. Various sensors are used to detect different parameters from the collected milk samples. The microcontroller processes the data, and the results are shown on both an LCD screen and an IoT dashboard.

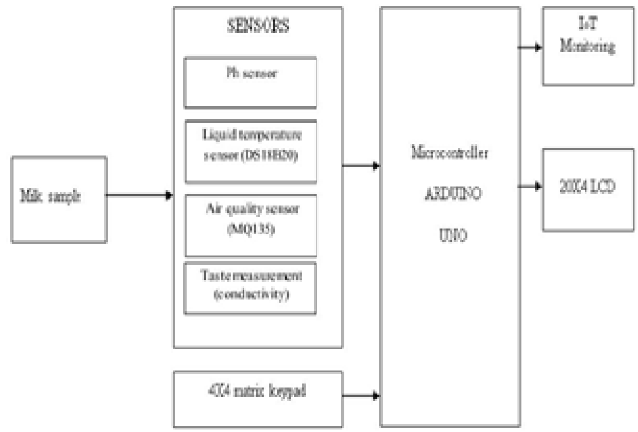


Fig.1 Block Diagram

Sample Preparation

Commercial raw cow milk samples were used alongside four adulterants: hydrogen peroxide, sodium salicylate, ammonium sulphate, and dextrose. Adulterants were added in two stages to create mixed samples with different concentrations, as outlined in Table 3. Initially, spectral readings were taken for the pure raw milk sample. Then, the pure milk sample was mixed with the first adulterant, sodium salicylate, at a rate of 5g in the sample tube. Spectral measurements were conducted using the same setup as for the pure milk sample.

Table 3 Design of sample preparation in 110ml of pure milk

Test Cases	Nature of Samples	Adulterant level mixture in pure milk (ml)
Case I	Raw cow Milk Sample	-
Case II	Sodium Salicylate	5*ml and10ml
Case III	Dextrose	5*ml and 10ml
Case IV	Hydrogen Peroxide	5*ml and 10ml
Case V	Ammonium Sulphate	5*ml and 10ml

To create the second sample, 5 milliliters of sodium salicylate adulterant were added again, resulting in a 10 milliliter contaminated sample. Table 4 provides details of the production process, including samples from different milk types.

Types of Milk Sample	Milk Fat	Solid Non - Fat
Standardized Milk	4.5	8.5
Buffalo Milk	5.0 – 6.0	9.0
Pure Cow Milk	3.0 – 4.0	8.5 – 9.0

Table 4 Types of samples taken for training

Spectral Data Collection

Table 5 shows the total number of samples tested in the experiment, which included one pure raw cow milk sample and four types of adulterants: sodium salicylate, dextrose, ammonium sulphate, and hydrogen peroxide. A total of 16,200 samples were tested, with 1800 samples for each type of milk and adulterant. Spectral observations were collected for at least five minutes per sample, with ambient light present. The multispectral sensor system had a sampling period of 150 ms and a rate of 6 samples per second.

Table 5 Spectral sample collection

S.no	Cases	Sampling rate /Total no of samples acquired
1.	Pure Milk	6/1800
2.	SodiumSalicylate(5ml) and(10ml)	6/1800
3.	Dextrose(5ml),and (10ml)	6/1800
4.	HydrogenPeroxide(5ml), and (10ml)	6/1800
5.	Ammonium Sulphate(5*ml,and (10ml)	6/1800

RESULTS AND DISCUSSION

Spectral Data Analysis

The spectrum data are analyzed to create the classifier. Plotting the spectrum samples helps understand how variables relate to each other and evaluate similarity within the data sets.

Figure 2 shows a graph of photon count against channel wavelength. In the range of 730 to 760 nm, which is in the ultraviolet area, we can distinguish between pure cow milk and milk with added ammonium sulphate. However, between 810 and 900 nm, the spectral response for both types of samples is similar, so we can't use this range to tell them apart.

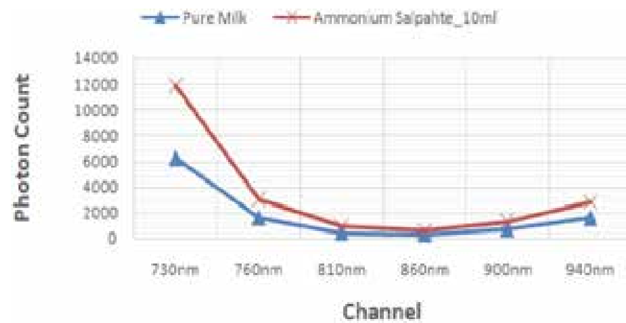


Fig. 2 Spectral Response (730nm - 940nm) for Pure Cow Milk and 10ml Added Ammonium Sulphate

Figure 3 illustrates the NIR spectral response for both pure cow milk and a mixture with 10 ml/g of ammonium sulphate. Differences in photon counts between the sample classes are noticeable in the NIR wavelength range of 410nm to 535nm. The graph in Figure 3 demonstrates that various photon counts are generated across the entire spectrum sensor wavelength range, enabling dependable data classification.

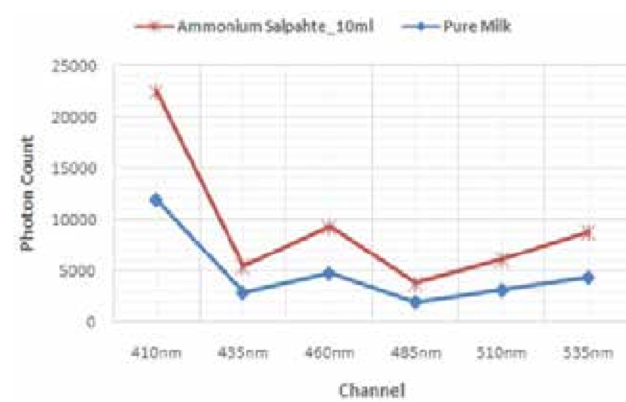


Fig. 3 Spectral Response(410nm-535nm) for Pure Cow Milk Vs 10ml/g Added Ammonium Sulphate

Figure 4 shows deviations between the spectra of pure raw milk and milk mixed with 10 ml of ammonium sulphate. Analysis indicates that the adulterant can be identified and distinguished from the pure milk sample. The wavelength range for this difference is 410 nm to 535 nm, corresponding to the sensor's NIR spectral response. In Figure 4, the peak response for pure milk is represented by a dotted line at a photon count of 12000. The diamond line for the ammonium sulphate mixture shows spectral response photon counts lower than 12000. Therefore, using NIR, we can differentiate between adulterated and non-adulterated samples.

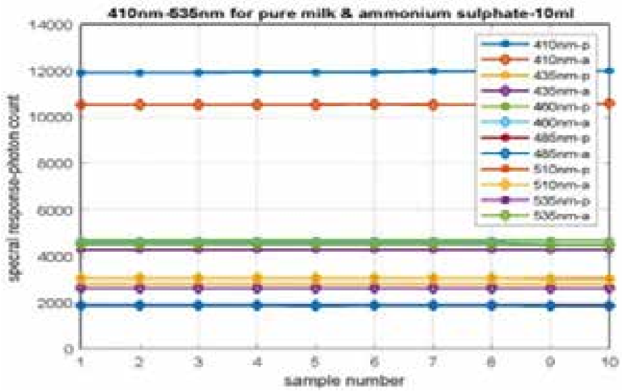


Fig. 4 Arduino Serial Plotter for Pure Cow Milk and 10ml/g Added Ammonium Sulphate

To visualize and confirm if the adulterant can be classified using raw spectrum samples, clustering analysis is employed, specifically the K-Means clustering technique. In K-means clustering, new groups are formed by calculating the centroid point within the dataset and using the mean points of the groups. In Figure 5, the cluster assignment graph shows dotted dots representing pure cow milk forming one cluster with sample numbers ranging from 4000 to 8000, with a cross mark as the centroid. Another cluster, formed by ammonium sulphate, is represented by dotted dots ranging in sample numbers from 0 to 4000, with a cross mark as its centroid. The data points for each distinct sample closely match their respective clusters.

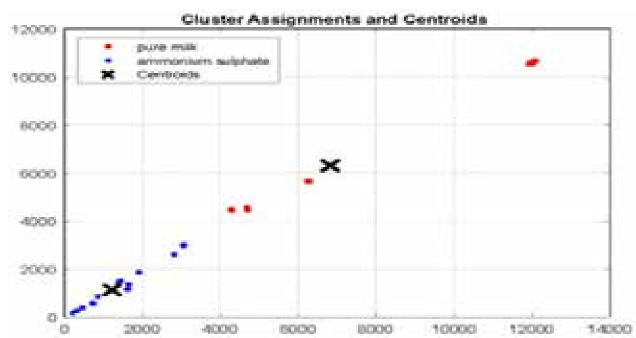


Fig. 5 K-Means Clustering Analysis for Pure Cow Milk and Ammonium Sulphate

CONCLUSION

In conclusion, this paper has provided a comprehensive review and analysis of IoT-enabled solutions for detecting and preventing milk adulteration. Through a thorough examination of existing literature, case studies, and technological developments, we have elucidated the effectiveness, challenges, and future prospects of these innovative approaches.

Our exploration of sensor technologies, data analytics techniques, and communication protocols has underscored the critical role of IoT in safeguarding milk quality and ensuring consumer trust. By harnessing the power of real-time monitoring and data analytics, IoT-enabled solutions offer unprecedented insights into milk quality parameters, enabling timely detection and intervention in cases of adulteration.

Looking ahead, continued research and innovation are essential to further refine and optimize IoT-enabled solutions for milk adulteration detection and prevention. By fostering collaboration between researchers, industry stakeholders, and policymakers, we can work towards a future where milk adulteration is effectively mitigated, ensuring the safety and integrity of this vital commodity for generations to come.

REFERENCES

1. F. Mabood, L. Ali, R. Boque, G. Abbas, F. Jabeen, Q. M. I. Haq, J. Hussain, A. M. Hamaed, Z. Naureen, M. Al-Nabhani, M. Z. Khan, A. Khan, and A. Al-Harrasi, “Robust Fourier transformed infrared spectroscopy coupled with multivariate methods for detection and quantification of urea adulteration in fresh milk samples,” Food Sci. Nutrition, vol. 8, no. 10, pp. 5249-5258, Oct. 2020.

2. E. Albanell, P. Rohman, G. Caceres, E. Molina, and A. Gargouri, “Determination of Fat, Protein, and Total Solids in Ovine Milk By Near-Infrared Spectroscopy,” Journal of Association of Official Analytical Chemists (AOAC), vol. 12, pp. 753–758, December 1999.

3. O. Ahmed Ramadan, S. Arora, V. Sharma, D. Raj, M. Ram, and K. Kishore, “Authentication analysis of Butter from Beef Fat using Fourier Transform Infrared (FTIR) Spectroscopy Coupled with Chemometrics,” International Food Research Journal, vol. 20, pp. 1383-1388, December 2012.

4. M. Chakraborty and K. Biswas, “Limit of detection for five common adulterants in milk: a study with different fat percent,” IEEE Sensors J., vol. 18, no. 6, pp. 2395–2403, 2018.

5. R. J. Yang, R. Liu, and K.X. Xu, “Evaluation of Raw Milk for Common Commercial Additives and Heat

Treatments," International Journal of Food Safety, vol. 15, pp. 7-10, February 2011.

6. S. Rehman, A. Borin, M. F. Ferrao, C. Mello, D. A. Maretto, and R. J. Poppi, "Application of 2D Correlation Infrared Spectroscopy to Identification of Adulterated Milk using NPLS-DA Method," in Third International Conference on Instrumentation, Measurement, Computer, Communication and Control, vol. 28, pp. 259-263, May 2011.

7. M. M. Chakrabarty, C. Bandyopadhyay, D. Bhattacharyya, and A. K. Gayen, "Detection of Adulteration, Chemical Composition and Hygienic Status of Milk Supplied to Various Canteens of Educational Institutes and Public Places in Faisalabad," The Journal of Animal and Plant Sciences, vol. 23, pp. 119-124, November 2013.

8. M. Bellal Hossain, John-hyeon Chang, Jungil Park, Youngmi Pak, and James Jungho Pak, "Fitting Improvement using a New Electrical Circuit Model for the Electrode Electrolyte Interface," in 3rd International IEEE Conference Neural Engineering, Kohala Coast, Hawaii, vol. 1, pp. 2-7, May 2007.

9. M. Nielen, H.J. Biggadike, I. Ohnstad, R.A. Laven, and J.E. Hillerton, "Physiochemical Characteristics of Various Raw Milk Samples in a Selected Dairy Plant of Bangladesh," International Journal of Engineering and Applied Sciences, vol. 03, pp. 2305-8269, January 2013.

10. P. Zachar, G. Enne, D. Elez, F. Fondrini, I. Bonizzi, M. Feligini, and R. Aleandri, "Design and Construction of a System for Measuring the Concentration of Water in Milk," Journal of Dairy Science, vol. 75, pp. 606-614, July 2002.

11. Gupta, P., S. Arora, V. Sharma, D. Raj, M. Ram, "Status of Milk Adulteration in Some States of North India," Indian Journal of Dairy Science, vol. 57, pp. 65-66, April 2004.

12. Anand, S. K., "Quality Assurance and Public Health Safety of Milk and Milk Products: A Review," The Indian Journal of Animal Sciences, vol. 7, pp. 282-287, November 2004.

13. L. M. Fonseca, M. Baumgartner, M. Flock, P. Winter, "Evaluation of Fourier Transform Infrared Spectrometry for the Routine Determination of Urea in Milk," Journal of Agricultural and Food Chemistry, vol. 58, pp. 599-602, March 2003.

14. J. Campbell, S. Feng, "Exploring Near and Mid-infrared Spectroscopy to Predict Trace Iron and Zinc Contents in Powdered Milk," Journal of Agricultural and Food Chemistry, vol. 57, pp. 1697-1704, January 2009.

15. Cozzolino, D., Downey, M., Smyth, H. E., Gishen, M., "Feasibility Study on the use of Visible and Near-infrared Spectroscopy Together with Chemometrics to Discriminate between Commercial White Wines of different Varietal Origins," Journal of Agricultural and Food Chemistry, vol. 51, pp. 7703-7708, October 2003.

16. A. Fassio, A. Gimenz, E. Fernandez, D. Vaz Martins, D. Cozzolino, "Prediction of Chemical Composition in Sunflower and Silage by Near Infrared Reflectance Spectroscopy," Journal of Near Infrared Spectroscopy, vol. 15, pp. 201-207, November 2007.

17. Downey, G., Esbensen, K., Briandet, R., Wilson, R. H., Kemsley, E. K., "Near- and mid-Infrared Spectroscopies in Food Authentication," Journal of Agricultural and Food Chemistry, vol. 45, pp. 4357–4361, April 1997.

18. Z. Haenlein, E. N. Escobar, "Effect of Parity and Milk Production on Somatic Cell Count and Composition of Goat Milk," Journal of Agricultural and Food Chemistry, vol. 17, pp. 269–274, March 1995.

19. M. Abdulla, K. K. Rajah, H. Michael, "Quantitative Techniques in the Measurement of Milk Adulteration in Peshawar," Pak Int. J. Dairy Technology, vol. 52, pp. 20-25, November 1999.

20. D. A. Joslyne, G. L. Catignani, H. E. Swaisgood, "Analytical Methods for the Species Identification of Milk and Milk Products," Critical Reviews in Food Science and Nutrition, vol. 45, pp. 563-585, August 2005.

21. E. R. Kenawy, F. Accum, "An Optoelectromechanical Sensor for Detecting Adulteration in Anhydrous Milk Fat," IEEE Sensors Journal, vol. 14, no. 9, September 2014.

22. J. Kelly, C. Petisco, G. Downey, "Application of Fourier Transform Mid-infrared Spectroscopy to the Discrimination between Irish Artisanal Honey and such Honey Adulterated with Various Sugar Syrups," J. Agric. Food Chem., vol. 54, pp. 6166–6171, August 2006.

23. J. Rozenfeld, G. Abernethy, K. Higgs, "Rapid Detection of Economic Adulterants in Fresh Milk by Liquid Chromatography–Tandem Mass Spectrometry," Journal of Chromatography, vol. 1288, pp. 10–20, October 2013.

24. E. Molina, P. Caceres, G. Caja, A. Gargouri, "Determination of Fat, Protein and Total Solids in Ovine Milk by Near-infrared Spectroscopy," Journal of Association of Official Analytical Chemists (AOAC), vol. 82, pp. 753-758, January 1999.

25. A. Borin, M. Ferrao, R. Poppi, "Least-squares Support Vector Machines and Near Infrared Spectroscopy for Quantification of Common Adulterants in Powdered Milk," Journal of Agricultural and Food Chemistry, vol. 57, pp. 25–32, December 2006.

26. Z. A. Syahariza, Y. B. Che Man, M. E. S. Mirghani, "Detection of Lard Mixed with Body Fats of Chicken, Lamb, and Cow by Fourier Transform Infrared Spectroscopy," Journal of the American Oil Chemists' Society, vol. 78, pp. 753–761, April 2001.

27. W. P. William, K. Norris, "Estimating Fatty Acid Content in Cow Milk using Mid-Infrared Spectroscopy," Journal of Dairy Science, vol. 1, pp. 35-45, March 2001.

28. H. J. Luinge, M. F. Kerkhof Mogot, J. Koops, R. Neeter, K. J. Slangen, H. van Hemert, O. Kooyman, H. Wooldrik, "Determination of the Fat, Protein, and Lactose Content of Milk using Fourier Transform Infrared Spectroscopy," Journal of Agricultural and Food Chemistry, vol. 36, pp. 185-195, February 1998.

29. A. Borin, M. F. Ferrao, C. Mello, D. A. Maretto, R. J. Poppi, "Least-squares Support Vector Machines and Near-infrared Spectroscopy for Quantification of Common Adulterants in Powdered Milk," Journal of the Association of Official Analytical Chemists (AOAC), vol. 579, pp. 25–32, March 2006.

30. B. Aernouts, E. Polshin, W. Saeys, J. Lammertyn, "Rapid Detection and Quantification of Milk Adulteration using Mid-infrared Spectroscopy and Chemometrics Analysis," Journal of Food Science, vol. 705, pp. 88–97, January 2011.

31. B. Aernouts, E. Polshin, W. Saeys, J. Lammertyn, "Rapid Detection and Quantification of Milk Adulteration using Mid-infrared Spectroscopy and Chemometrics Analysis," Journal of Food Science, vol. 705, pp. 88–97, January 2011.

32. R. Gupta, S. Wadhwa, A. Mathur, A. K. Dubey, "Designing of a Microelectrode Sensor based Label-Free Milk Adulteration Testing System," IEEE Sensors Journal, vol. 17, no. 18, pp. 6050-6055, September 2017.

33. G. Bilge, B. Sezer, K. E. Eseller, H. Berberoglu, A. Topcu, I. H. Boyaci, "Determination of Whey Adulteration in Milk Powder by Using Laser-Induced Breakdown Spectroscopy," Food Chemistry, vol. 212, pp. 183-188, December 2016.

34. S. Bhadra, D. J. Thomson, G. E. Bridges, "A Wireless Passive pH Sensor for Real-Time In Vivo Milk Quality Monitoring," 2012 IEEE..

35. C. de Souza Gondim, R. G. Junqueira, S. V. C. de Souza, I. Ruisánchez, M. P. Callao, "Detection of Several Common Adulterants in Raw Milk by Mid-Infrared Spectroscopy and One-Class and Multi-Class Multivariate Strategies," Food Chemistry, vol. 230, pp. 7-68, September 2017.

Transaction Tracking Using Blockchain Smart Contract

Akshay Shetye
akshay.shetye@famt.ac.in

Hashim Shakeel Hawaldar
hashimhawaldar2002@gmail.com

Shreyas Deepak Jangam*
shreyasjangam010@gmail.com

Hruturaj Dhakalu Davri
davariruturaj1513@gmail.com

Suraj Maruti Sawant
sawantsuraj8413@gmail.com

Department of Computer Science & Engineering
Finolex Academy of Management and Technology
Ratnagiri, Maharashtra

ABSTRACT

The objective of this research is to leverage smart contracts to enhance transaction tracking in blockchain systems. We propose a novel approach that combines the immutability and transparency of blockchain with the automation capabilities of smart contracts to create a robust and efficient transaction tracking system. The core components of our approach include the development of smart contracts that record transaction details, timestamp them securely, and trigger predefined actions based on predefined conditions. The paper discusses the key benefits of using smart contracts for transaction tracking, such as Enhancing security, cutting down on mistakes, doing away with the need for middlemen, and raising overall monitoring process efficiency. Furthermore, we delve into the technical implementation details, including the choice of blockchain platform, smart contract development, and integration with existing systems. To validate the effectiveness of our proposed approach, we present case studies andreal-world examples from several sectors, including as healthcare, banking, and supply chain management. These examples demonstrate how smart contract- based transaction tracking can streamline processes, reduce costs, and enhance trust among participants. This research highlights the significant potential of blockchain smart contracts in revolutionizing transaction tracking across multiple industries.

KEYWORDS *: Blockchain, Smart contract, Transaction tracking, Donation tracking, Fund tracking, Solidity.*

INTRODUCTION

Transaction tracking using blockchain smart contracts addresses several critical needs across various industries. Here are some of the key needs and benefits of implementing this system:

Transparency and Trust: Transactions on blockchain are transparent and trustworthy because of its decentralized and unchangeable structure. Smart contracts execute automatically and are tamper-resistant, reducing the risk of fraud or manipulation.

Reduced Intermediaries: Conventional transactions sometimes include a number of middlemen, which increases complexity, delays, and expenses. Smart contracts do away with the need for middlemen process simplification, and transaction fee reduction.

Immutable Records: Once a transaction is recorded on the blockchain, it automatically upon the fulfillment of predetermined criteria. Because to this automation, less time required for manual processing, increasing the speed of transactions and reducing errors.

Security: Strong security features are offered by blockchain technology. Because transactions are encrypted, it is very impossible for unauthorized parties to view or change transaction data.

Audibility: All transactions recorded on a blockchain are traceable and auditable. This feature is crucial for compliance, accountability, and regulatory purposes across a number of sectors, including supply chain management and finance.

Cost Savings: Through process automation and the removal of middlemen, transaction tracking using smart contracts can significantly reduce operational costs. This is particularly beneficial in industries with high transaction volumes.

Global Reach: Blockchain technology functions globally, facilitating cross-border transactions without the use of middleman.

Real-time Tracking: Smart contracts can provide real-time tracking of transactions, assets, or goods. This is valuable in supply chain management, where knowing the exact location and condition of goods is crucial.

Smart Contract Extensibility: Smart contracts can be customized and extended to suit specific business needs. This flexibility allows for the development of tailored solutions for various industries.

Decentralization: Blockchain networks are typically decentralized, meaning that no single entity possesses command over the network. Because of its decentralization, there is less chance of SPOF and enhances system resilience.

Immutable Agreements: Smart contracts can also be used for creating and executing agreements, ensuring that parties involved adhere to the terms and conditions outlined in the contract.

Enhanced Compliance: Blockchain-based transaction tracking can help businesses comply with industry-specific regulations and standards, automating compliance checks and reporting.

Improved Customer Experience: Faster, more transparent, and cost-effective transactions can enhance the customer experience, leading to higher satisfaction and loyalty.

Data Integrity: Blockchain ensures data integrity by design. Because blockchain data is immune to data alteration, it ensures the accuracy of transaction records.

In summary, transaction tracking using blockchain smart contracts addresses the need for increased transparency, efficiency, security, and trust in various industries. It offers a transformative solution to streamline processes, reduce costs, and improve the overall reliability of transactions and agreements.

LITERATURE REVIEW

Various proposals in relation to donation systems supported by different multiple blockchain systems exist. [1]. In E. Shaheen et al., A fresh contribution concept was put forward, bringing in many new players that oversee the Procedure of contribution and dispel any doubts regarding the charity. Donors might be able to follow every donation on a blockchain, given them insight into the whereabouts and purposes of their funds.

In [2] the authors propose a system consisting of important users who fall into three categories: government entities, non- governmental organizations, and donors/beneficiaries. These users will hold accounts in the blockchain network, and each one of them will have a unique 160 bit id that allows them to be identified within the product to the buyers. A smart contract is a collection of rules that are defined to carry out transactions on a blockchain. The Ethereum blockchain is used by the smart contract to record all transactions that take place and save them on the blockchain when states change. Thus, this is frequently useful for monitoring the variety of items in the supply chain. According to the author, the physical approach, which involved a group of people carrying out quality inspections to confirm the goods, is less secure than the suggested Origin Chain system for product tracking. They have employed Blockchain, or distributed ledger technology, is used to store the transaction data. The distributed ledger database system distributes changes to any data among several nodes (devices) via a peer-to-peer network, whereupon the change is recorded as a state transition of a account number. With their 256-bit private key, they may sign transactions, access their accounts, and do other operations.

In [3], The author discusses its experience with OriginChain and argues that one important industry that is touched by blockchain technology is traceability management. Following an item's origin through a supply chain is essential to verifying its legitimacy and offering a trustworthy source. Transition This enables any transaction to be traced back to the blockchain when needed.

In Future Technologies Conference (FTC) 2020 Proceedings, Volume 2 [4], Sergey et.al propose a system where It will be necessary to record donations and transfers of charity cash using the REST API. The system also includes a Telegram bot that communicates with users when they make fresh donations. The user provides this bot with the amount they wish to donate to charity, and it provides the ID for that gift. The user may then trace the precise location of the money' expenditure by entering this ID to view comprehensive details about the donation on the website or in the Telegram bot. This bot's functionality is comparable to that of the website.

[5]There exist numerous deployed applications which are currently running online using decentralized or distributed blockchain networks. One of them is AidChain which provides a blockchain-based crowd funding platform. It allows donors to make a traceable charity donation via blockchain technology and provides its own crypto coin known as AidCoin to make donations. Another is BitGive

[6] Which is the first charity and humanitarian organization to use Blockchain and Bitcoin technologies. Through the sharing of financial data and direct project participants in Bangladesh and Jordan, it leverages the platform to help nonprofits give donors transparency and accountability while allowing them to safely access and receive various forms of aid from various organizations through a single access point.

[7]organizations via one access point. The Participating companies can freely utilize the open-source software-based technical blockchain infrastructure that powers the network. Members of the Building Blocks network can also download the deployed applications for free. In essence, Building Blocks is an assembly of blockchain nodes, which are independent computer servers that are managed by each participating business. Together, they form a blockchain network dedicated to humanitarian causes.

[8] that offers a neutral platform for cooperation, real-time safe information sharing, and transactions. There is no ownership hierarchy on the network, therefore all members are impartial. results in real time. They have cooperated with NGOs such as Heifer International, Code to Inspire, and Save the Children. However, the widest and most recognizable use of blockchain for donation was seen by the World Food Programme which employed a blockchain network named Currently supporting one million people, "Building Blocks" is the greatest use of blockchain technology for humanitarian aid worldwide. Organizations share equal ownership, control, and governance over the network, and each member contributes equally to its maintenance.

PROPOSED SYSTEM

Blockchain Infrastructure: At the core of the system lies a blockchain network, which consists of a distributed decentralized ledger among several nodes or computers. Because every node keeps a copy of the whole blockchain, redundancy and resilience against single points of failure are ensured. The blockchain operates on a consensus mechanism, wherein users accept the legitimacy of transactions by following a pre-established procedure, such proof of stake (PoS) or proof of work (PoW).

Smart Contracts: On the blockchain, self-executing computer programs known as "smart contracts" are essential for automating and facilitating transactions. These agreements include predetermined guidelines that control the performance of particular tasks upon the fulfillment of particular requirements. In the framework of open charitable transactions tracking, smart contracts encode rules for receiving, disbursing, and tracking donations. They serve as the backbone of the system, ensuring trustless and tamper-proof execution of transactions without the need for intermediaries.

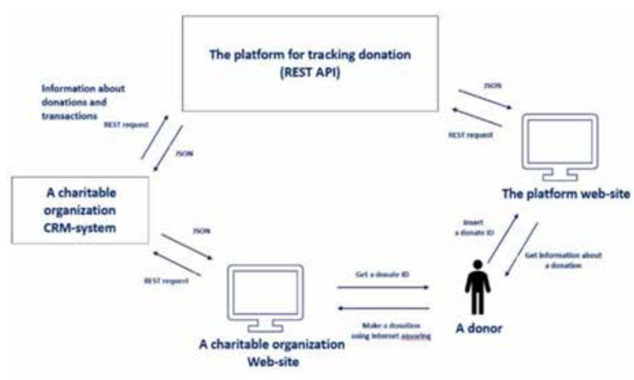


Fig. 1. Transaction Tracking Architecture

Donor Interaction: The process begins when a donor initiates a donation through the blockchain-based platform. Donors interact with the platform through a user-friendly interface, where they can specify the amount of donation, select a charitable cause or organization, and set any additional preferences or conditions for their contribution. Once the donation details are confirmed, the platform triggers the execution of a smart contract corresponding to the selected charity or cause.

Transaction Verification and Recording: Upon initiation, the donation transaction is broadcasted to the blockchain network for verification and validation by network participants, also known as miners or validators. These participants validate the transaction by confirming its compliance with the predefined rules encoded within the smart contract. The transaction is entered into the blockchain when it has been verified. as a new block, forming a sequential chain of blocks linked through cryptographic hashes.

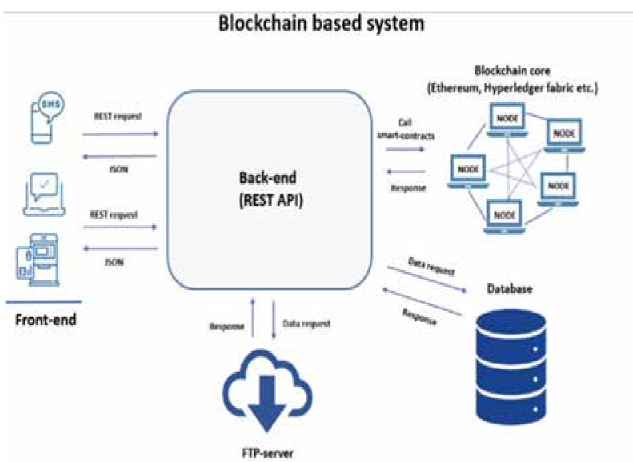


Fig. 2. Blockchain System

Real-Time Tracking and Transparency: The contribution transaction becomes transparent and unchangeable once it is registered on the blockchain, making it accessible to all users of the network. Donors can access real-time updates on the status and utilization of their donations by querying the blockchain through the platform's interface. Smart contracts facilitate the tracking of donations from the point of receipt to their eventual allocation and expenditure by charitable organizations, ensuring transparency and accountability throughout the process.

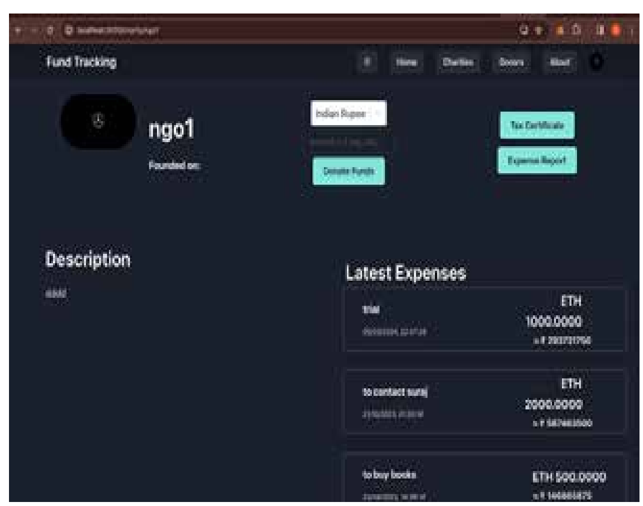
Automated Disbursement and Accountability: Based on predefined rules encoded in the smart contract, donations are automatically disbursed to the designated charitable organizations or beneficiaries. These disbursements are transparently recorded on the blockchain, providing an auditable trail of transactions for accountability purposes. Charitable organizations, in turn, can access funds in a timely manner and provide real-time updates on project progress and expenditures, further enhancing transparency and donor confidence.

Security and Immutability The blockchain network's decentralized structure combined with encryption methods such as hashing and digital signatures, ensures the security and immutability of transaction records. Once Transactions that are stored on the blockchain cannot be changed or removed, providing a tamper-proof and auditable record of all donation activities.

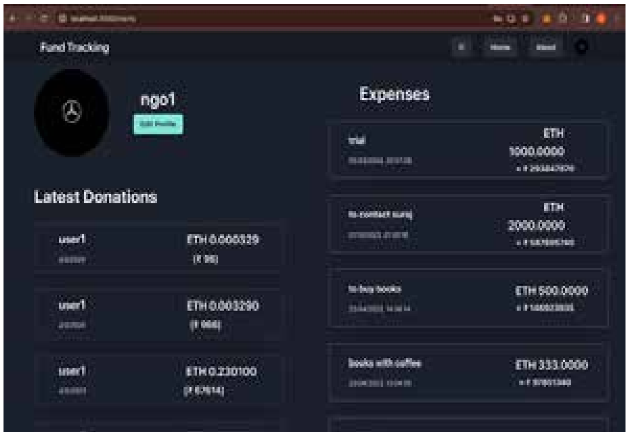
In summary, the internal workings of utilizing blockchain smart contracts for transparent charity transaction tracking involve leveraging blockchain infrastructure, deploying smart contracts to automate and enforce transaction rules, facilitating donor interaction through user-friendly interfaces, verifying and recording transactions on the blockchain, enabling real-time tracking and transparency, automating disbursements while ensuring accountability, and ensuring security and immutability through cryptographic techniques. This systematic approach enhances transparency, trust, and efficiency in philanthropic endeavors, empowering donors and charitable organizations alike.

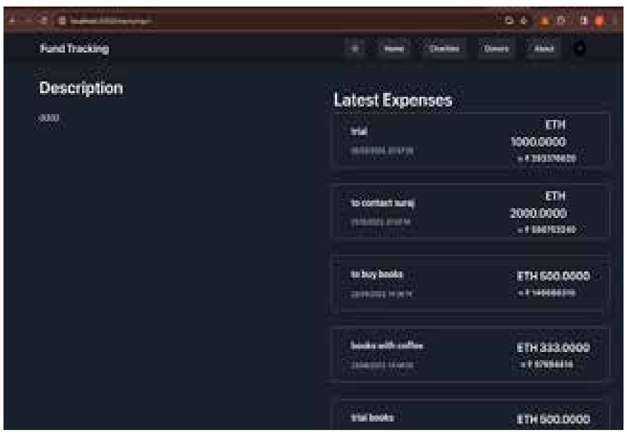
RESULTS

User side



Admin side





SUMMARY

Funds tracking through blockchain smart contracts revolutionizes financial transparency and accountability. Leveraging blockchain technology, smart contracts automate and securely execute fund transactions, eliminating intermediaries and reducing the risk of errors or fraud. Through immutable distributed ledgers, every transaction is recorded and time stamped, ensuring a transparent audit trail accessible to all authorized parties. Smart contracts facilitate real-time monitoring of fund movements, enhancing efficiency and trust in financial operations. Participants can track funds from inception to destination seamlessly, mitigating delays and disputes. Additionally, smart contracts enforce predefined rules encoded within the blockchain, automating compliance and reducing administrative burdens. This innovative approach ensures that funds are managed with unprecedented accuracy and integrity. From charitable donations to investment portfolios, blockchain-based fund tracking offers unparalleled transparency and security, fostering trust among stakeholders. As a result, organizations can streamline operations, reduce costs, and enhance accountability, ultimately leading to a more efficient and trustworthy financial ecosystem.

REFERENCES

1. E. Shaheen et al., “A Track Donation System Using Blockchain.’ 2021International Conference on Electronic Engineering (ICEEM), 2021, pp. 1-7, doi:ICEEM52022.2021.9480649

2. A. Singh, R. Rajak, H. Mistry and P.Raut,”Aid, Charity and Donation Tracking System UsingBlockchain,”2020 4th International Conference on Trends in Electronics and Informatics (ICOEI)(48184), 2020, pp. 457-462, doi: 10.1109/ICOEI48184.2020.9143001.

3. Lu, Q., & Xu, X, (2017),Adaptable blockchain-based systems: A case study for product traceability, IEEE Software, 34(6), 21-27

4. Avdoshin, Sergey & Pesotskaya, Elena. (2021). Blockchain in Charity: Platform for TrackingDonations. 10.1007/978-3- 030-63089-8_45.

5. https://tracxn.com/d/companies/a idchain.co

6. https://www.bitgivefoundation.org

7. https://innovation.wfp.org/projec t/building-blocks

8. https://www.semanticscholar.org/paper/Adaptable-Blockchain- Based-Systems

Water Quality Measurement using Arduino

Anand Acharya
acharyaanand0@gmail.com

Harshwardhan Avghade
harshvardhanavghade558@gmail.com

Esakkimuthu Konar
kkonar04@gmail.com

Department of Industrial Electronics
VPM Polytechnic
Thane, Maharashtra

ABSTRACT

Water quality is crucial for both human health and environmental sustainability. Despite efforts, data from the Human Rights Commission indicates that millions of people still consume polluted water in our country, leading to waterborne diseases. Traditional manual methods of water monitoring are time-consuming and prone to errors, necessitating the adoption of new monitoring techniques. The primary objective of this project is to develop a system for regular monitoring of water quality parameters. Using Arduino Uno as the core controller, data from sensors measuring turbidity, pH, and temperature are collected and analyzed to determine water safety levels. This cost-effective system offers practical applications, particularly in ensuring clean drinking water, by providing real-time monitoring of water quality across various locations.

KEYWORDS *: Arduino UNO, PH sensor, Temperature sensor, Turbidity sensor and LCD display.*

INTRODUCTION

We are using Arduino a smart mini-computer, PH Sensor, and Turbidity Sensor which helps us to check how muddy water is. Connecting the sensor to Arduino is like building a tiny water detective. The sensor measures how much light goes through the water and the controller tells us if it's clear or not. It's an easy way to ensure the water we use is clean and safe. Connecting a sensor to Arduino and imagine this sensor as a knowing eye, scanning the water for clarity. It sends signals to the Arduino, which then translates them into meaningful data. Approximately, it helps us distinguish between crystal-clear water and water that may have impurities. For the survival of human beings and other living organisms water is the initial element. The water of high quantity is important for human health and should be used for drinking, cooking, and household use.

The primary objective of utilizing an Arduino, PH Sensor, and turbidity sensor for water quality measurement is to assess water clarity, distinguishing between clear and cloudy water. This is vital as clear water is generally considered safe for both humans and the environment, with turbidity serving as a key indicator of water cleanliness and purity. The Arduino-based turbidity sensor operates by measuring light transmittance to detect suspended particles, offering a simple and cost-effective means of monitoring water quality and ensuring optimal conditions.

By employing this system, changes in water clarity can be promptly detected, serving as an early warning sign for potential pollution or contamination. Regular monitoring facilitated by this setup is crucial in maintaining water quality standards for various uses such as drinking, bathing, and other domestic or industrial purposes.

LITERATURE REVIEW

Scientists are tirelessly working on monitoring water quality to ensure the health and well-being of future generations. Various innovative approaches have been proposed to develop effective real-time water quality monitoring systems. For instance, Mithila Barbade and Shruti Danve proposed a project aiming to replace traditional laboratory testing with remote sensing techniques, utilizing sensors, base stations, remote stations, and wireless communication links for continuous monitoring [2]. Similarly, Geetha S. and

Gauthami S. presented a paper on an Internet of Things (IoT) supported real-time water quality monitoring system, which provides a comprehensive review of existing research in this field and offers an easy-to-use IoT-based method for checking water quality, complete with an alarm system to signal monitoring issues [3].

Additionally, Nikhil Kediahs presented a study on water quality monitoring for rural areas, covering various real-time monitoring methods, sensors, controlling processors, government involvement, and cloud-based data storage [4]. Another notable study by Prof. M.U. Phutane, Priyanka Kawale, Pradnya Khot, and Pranali Gavali proposed a water monitoring system using Arduino interfaced with LabVIEW, employing sensors for temperature, turbidity, and pH to transmit data to LabVIEW for display on a PC [5]. These endeavors contribute significantly to advancing water quality monitoring technologies for better environmental and human health outcomes.

PROPOSED METHODOLOGY

The overall model is shown in Fig. The block diagram consists of a turbidity Sensor, PH Sensor Temperature Sensor, Arduino UNO, and LCD Display.

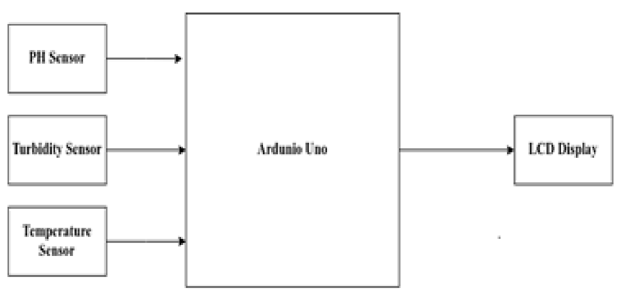


Figure 1. Block Diagram

Turbidity Sensor

The TSW-30- based turbidity sensor module uses the optical principle to determine the turbidity level based on the solution's transmittance and scattering rate. Within the sensor is a phototransistor and an infrared emitting diode. The phototransistor is in charge of absorbing the light, while the infrared emitter is in charge of producing the infrared light. The amount of light that gets through depends upon the turbidity of the water. The more light transmitted and the greater the current, the lower the degree of turbidity. Alternatively, less light is transferred and there is less current [6].

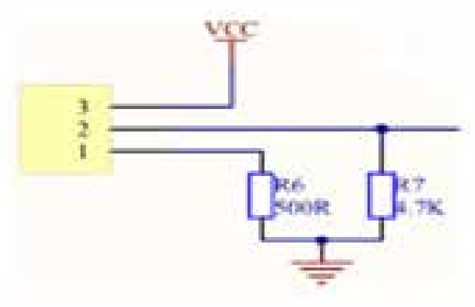


Figure 2. Turbidity sensor module circuit

Arduino UNO

The latest version of the well-known open-source microcontroller board from the Arduino family is called the Arduino Uno. It is built around the Ate mega 328P microprocessor and has many improvements over the Arduino Uno, its processor. The addition of a new AT Mega 16U2 microprocessor, which serves as a USB-to-serial converter, is one of the Arduino Uno's biggest updates. With the help of this new microcontroller, the board can now be identified by a computer as a USB device, which facilitates programming and communication. Additionally, it makes communication between the board and the computer quicker and more dependable.

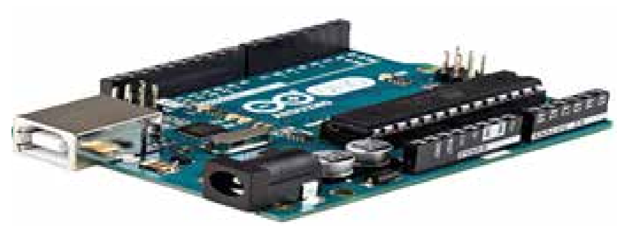


Figure 3. Arduino Uno

LCD Display

16*2 LCD Display is a popular type of alphanumeric display that is widely used in electronic equipment. The display consists of 16 columns and 2 rows of characters, hence the name 16*2. Each character is made of a matrix of pixels which are controlled by an LCD driver chip. When working on projects that need the display of text.16*2 LCDs are frequently utilized. It is an inexpensive, user-friendly display that works with a variety of microcontrollers, including the well-known Arduino platform.

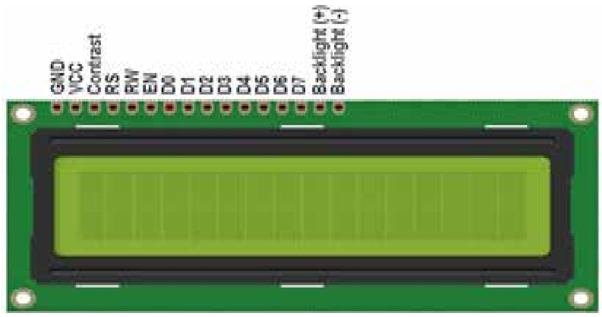


Figure 4. LCD Display

Arduino IDE

The Arduino IDE is a development environment (IDE) created especially for programming microcontroller boards made by Arduino. It is an easy-to-use interface for creating, developing, and uploading code to an Arduinoboard that is available as free and open-source software.

System Design Module

Proper sensors are chosen to measure the water's parameters in real-time. The main controller and these sensors are connected. The core controller used is the Arduino AT mega 328. The Arduino AT mega 328 is used to transform the analog signals from the sensors into digital signals. An ADC is used to transform these signals into a voltage range of 0 to 5V. When the core controller reads various sensor signals it uses an appropriate equation to transform the raw data into information. For user requirements, a visible element is connected to the system. The visible element used here is LCD [1].

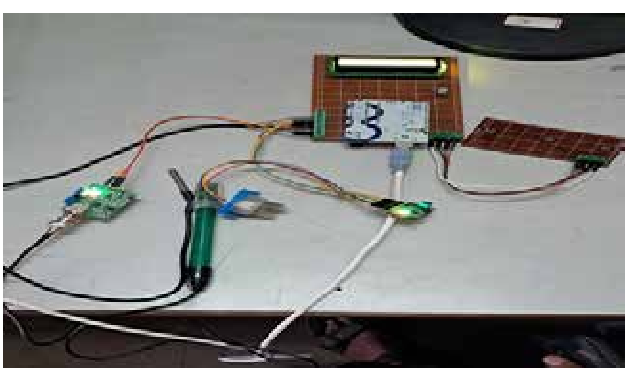


Figure 5. Actual Setup

RESULT

A specific number of samples drawn from several water sources are calculated in the proposed investigation. An appropriate model is implemented, complete with the necessary sensors and connecting devices, and is managed by an Arduino Uno as a central processor. Turbidity, water PH, and Temperature are important factors considered in this paper. Initially, two separate samples are studied to determine the corresponding values.

Sensors	Quality range	Test Sample-1	Test Sample-2	Test Sample-3
Turbidity	0 to 10	0 (Clean water)	58(Normal Dirty)	108 (Very Dirty)
	10 to 100 normal Dirty			
	up to 100 very dirty			
PH	1 to 14	7.34	6.83	6.50
Tempera-ture	25° to 30°	28°	27°	27°

FUTURE SCOPE

Future systems may see increased integration with IOT allowing for remote monitoring and control. IOT-enabled water quality monitoring networks could provide real-time data accessible from anywhere, improving efficiency and response time. Integration of multiple sensors beyond turbidities, such as PH, dissolved oxygen, and temperature sensors, could provide a more compressive analysis of water quality parameters. This sensor fusion approach enhances the understanding of overall water health.

CONCLUSION

In this study, a system to monitor water quality parameters has been proposed. Using a variety of sensors we may monitor parameters such as temperature, PH, and turbidity. This device operates at a very cheap cost and requires very little involvement. Water quality is important for different applications, including the chemical industry, residential and commercial buildings, and agriculture.

REFERENCES

1. Sabri M, Aswinth. P, Karthik. T and Bharath Kumar. C, "Water Quality Monitoring System based on IOT ".In 2020 5th International conference on Devices, circuits, and systems, 5-6 March 2020.
2. Mithila Barbade and Shruti Danve,"Real Time Water Quality Monitoring System". In International Journal of Innovative research in computer and communication engineering, 6 June 2015.
3. Geetha and Gauthami, "Internet of Things enabled real-time Water Quality Monitoring System". Atan International conference of Springer 2016.
4. Nikhil Kedia, "Water Quality Monitoring for Rural areas-A Sensor Cloud Based Economical Project".In 1st International conference on next generation computing Technologies Dehradun, India, 4-5 September 2015.
5. Prof. M. U. Phutane, Priyanka Kawake, Pradnya Khot, and Pranali Gavali,"Water Monitoring System using Aurdino with Lab view", in International Journal of Innovative Research in Electrical,Electronics,Instrumentation and Control Engineering 4th April 2022.
6. Chenwei Feng, Jiangunan yuan, Yusun and Junming You,"Design of Water Quality Monitoring System". In 2020 International Conference on Artificial Intelligence and Computer Engineering 23-25 October 2020.

Applications of Smart Materials in Mechanical Engineering: A Review

Rahul Kundiya*, Mukundrao Kadam
Department of Mechanical Engineering
BVDU College of Engineering
Pune, Maharashtra
✉ rahulkundiya1999@gmail.com
✉ makadam@bvucoep.edu.in

Jitendra Acharya
Department of Mechanical Engineering
VPM's MPCOE
Velneshwar, Maharashtra

Pradeep Jadhav
Principal & Professor
Bharati Vidyapeeth's College of Engg. for Women
Pune, Maharashtra
✉ pradeep.jadhav@bharatividyapeeth.edu

ABSTRACT

Smart materials, a class of materials capable of adaptive responses to external stimuli, have garnered significant attention in the field of mechanical engineering. This review paper offers a comprehensive overview of smart materials, their types, advantages, disadvantages, applications, and case studies in mechanical engineering. Their unique properties, including shape memory, piezoelectricity, and magnetostriction, enable tailored responses to environmental changes. This paper delves into the transformative potential of smart materials in mechanical engineering. The key characteristics of smart materials, such as adaptability and responsiveness, are highlighted, setting the stage for their relevance in mechanical engineering. The review covers various types of smart materials, including Shape Memory Alloys (SMAs), Piezoelectric Materials, Magnetostrictive Materials, Electroactive Polymers (EAPs), and Thermoelectric Materials. Each type is explored in terms of properties, applications, and recent developments. Smart materials offer numerous advantages, such as improved efficiency, adaptability, and cost-effectiveness. However, challenges such as cost, scalability, and technical limitations must be addressed to harness their full potential. Smart materials find diverse applications in mechanical engineering. Case studies exemplify their real-world utility, demonstrating how they enhance performance, durability, and sustainability in various sectors. The review discusses challenges and restraints in developing novel smart materials, including the need for cost-effective manufacturing, scalability, and ethical considerations. The paper concludes by outlining future research directions in smart materials, emphasizing advanced synthesis techniques, integration in construction, energy-efficient mechanical systems, environmental sensing, multidisciplinary collaborations, and regulatory considerations. In summary, smart materials represent a dynamic field with immense potential to revolutionize mechanical engineering. By understanding their properties, applications, challenges, and future prospects, this review paper aims to inspire further research, innovation, and cross-disciplinary collaboration in the realm of smart materials and their diverse applications

KEYWORDS *: Smart materials, Mechanical engineering, Applications, Shape memory materials, Piezoelectric.*

INTRODUCTION

The integration of smart materials in the realm of mechanical engineering has emerged as a revolutionary paradigm, driving transformative advancements in various applications. This paper delves into the profound implications and practical applications of these intelligent materials within the mechanical engineering domain. As our understanding of material science expands and innovative technologies come to the forefront, the potential for smart materials to redefine traditional mechanical systems becomes increasingly apparent. In this review paper, we embark on a journey through the world of smart materials and their profound impact on mechanical engineering. [1]

The challenges and opportunities in harnessing the unique properties of smart materials motivate this systematic review, aiming to synthesize existing knowledge and research on their applications in robotics, aerospace, automotive systems, biomedical devices, structural engineering, and more. The primary objectives include exploring various types of smart materials, understanding their characteristics, and analyzing their diverse applications. Research questions revolve around the adaptability and future potential of smart materials in addressing the evolving demands of mechanical engineering. The contributions of this review encompass providing researchers, engineers, students, and professionals with a comprehensive overview of the field, emphasizing the wide-ranging applications of smart materials. Smart materials have emerged as a driving force behind technological advancements in mechanical engineering [2]. Their unique properties, such as shape memory, piezoelectricity, and magnetostriction, have unlocked new frontiers of innovation. From creating adaptable and efficient robotic systems to improving the performance of aerospace components, smart materials have become indispensable in addressing the challenges of our modern world. Smart consists of the following attributes: Significant (S), Measurable (M), Appropriate (A), (Result Oriented) (R), and (Time Oriented) (T) [3].

Understanding their applications is not only essential for researchers and engineers but also for students and professionals seeking to stay at the forefront of mechanical engineering.

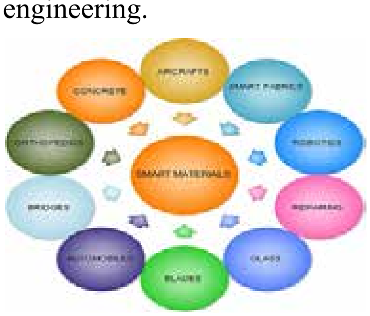


Figure 1.Wide applications of Smart Material [30]

This revolution introduced various smart materials as well as enhanced technologies for building and manufacturing materials. Smart materials are ones that vary their characteristics depending on the application [4]. It has an aim and a technique for achieving it [5]. Constraints such as needed strength, growing pollution, and scarcity have pushed practitioners to seek for novel smart materials [6,7]. The mechanical industry has accepted these revolutionary techniques and materials widely [8–12]. As shown in Fig. 1, smart materials are used in a variety of fields, including aerospace, environment electronics, civil engineering, electrical, healthcare, hospitality, agriculture, mechanical, sports, marine, and defence [13–21]. Given its adaptability, it will undoubtedly find more applications in the future [22–25]. There is still a need for greater research into these applications even though there have been studies in the field of mechanical engineering that examine the usage of smart materials. The many aspects of using such materials will be covered in this article, along with an overview of all related studies

TYPES OF SMART MATERIALS

In this review, we will explore several types of smart materials that have made significant contributions to the field of mechanical engineering. These materials include:

Shape Memory Alloy

Smart or intelligent materials may recover from deformation and take their original form. Shape memory alloy (SMA), one of the most popular varieties of these materials, is used in a variety of industries, including aviation, mass transit, the marine industry, the automotive industry, applications for consumer items, construction engineering, medical equipment, and other electronic gadgets [2]. Due to their direct connection and the impact of body temperature on its shape, this material is used in many different industries, including the production of surgical tools in the medical industry, orthodontics, and other purposes in healthcare. SMA apps for homes come with a number of functions, including smoke leak detection, alarms, security doors, and more. SMA is used in the industrial sector to produce incredibly tiny wire, which may then be used in the textile sector to knit garments, giving it the ability to shrink and other benefits in response to changes in body temperature and humidity. It can therefore help to warm or cool the human body depending on how sensitive it is to moisture and temperature, which will impact his mood. SMA is used in aerospace [1, 26].

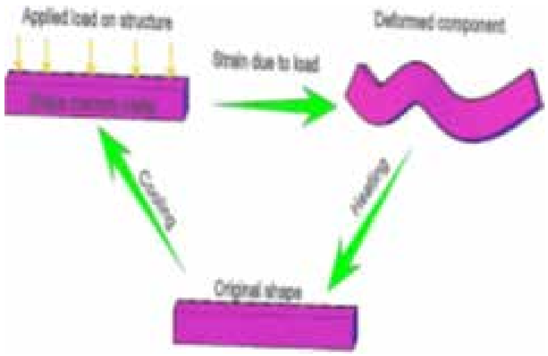


Figure 2. Behavior Pattern of Shape Memory Effect [30]

Piezoelectric Material

Actuators are one of piezoelectric's most significant applications. His labour is dependent on electrical input, which transforms it into mechanical work. The use of this material in air bags in the automotive industry is one of its most important uses. The piezoelectric will undergo a quick change in shape as a result of the magnetic field when electrical charge is applied. In addition to being used in sensors that generate an electric field in response to mechanical stimuli, this material has a wide range of other uses, such as the detection of vibrations in structures, microscopy, fibre optics, and photonics [1, 27, 30]. Previous research concentrated on the use of smart materials in a variety of fields, including fracture evaluation, increasing efficiency, fashion, and new biomimics. However, we found that there was little usage of smart materials in renewable energy [28, 29, 30].

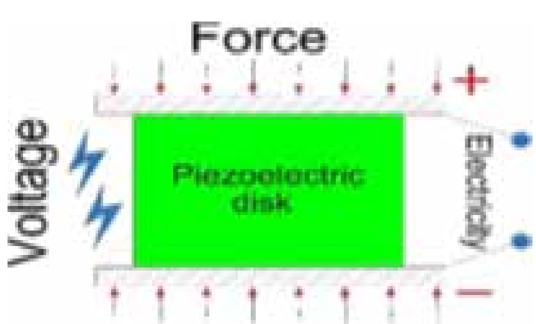


Figure 3. Piezoelectric Material

Magnetostriction Material

The word "magnetostriction" describes how magnetism may change a material's dimensions. One substance that could exhibit magnetostriction is terfenol-D, which can vary its electric current at the same rate as its electric field in response to magnetic fields. Due to its very low resistance, this material may be employed in stable conditions with low frequency. It should be mentioned that because to these materials' independent nature, they can generate a large amount of resistance at high frequencies (in the kHz range) [31].

When a magnetic field is given to the materials, the strain (deformation) changes and vice versa (Fig. 4). These materials are used as actuators and sensors. In their operation, they are analogous to ferromagnetic materials, with all particles aligning in line with the magnetic field applied [32].

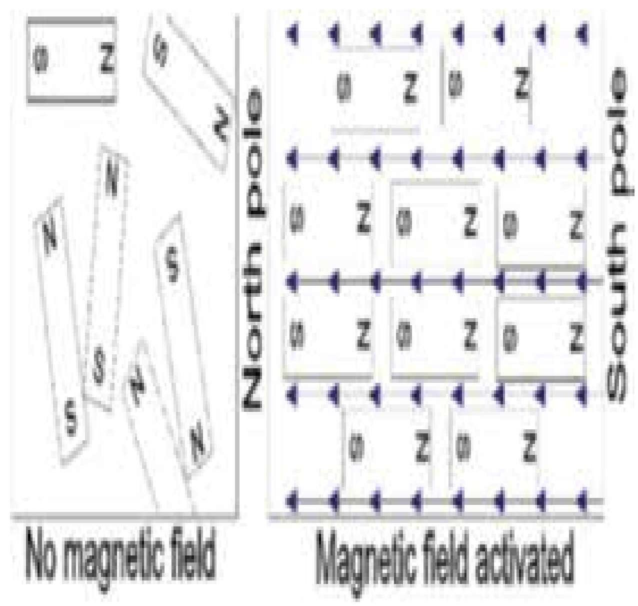


Figure 4. Magnetostrictive Materials

Electrostrictive Material

In terms of functioning, electrostrictive materials are comparable to piezoelectric materials. The difference between the two is around 2 degrees (Fig. 5). When an electric charge is supplied, all of the particles in such materials migrate and reorganize in a certain direction. All conductivity particles are aligned to increase the characteristics. This property has been employed in a number of smart structure applications [33,34].

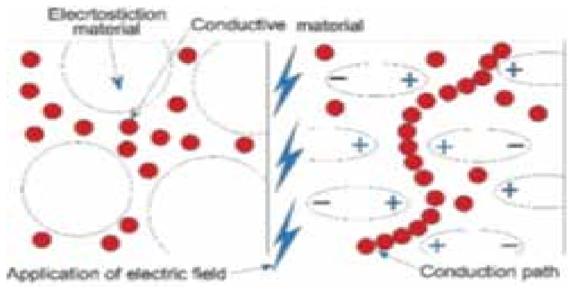


Figure 5. Electrostrictive Material

Rheological material

These materials exist in liquid form, but when a magnetic or electrical field is applied, they alter physical state. The fluidity of such a substance might vary from stiff to liquid (Fig. 6). Rheological materials have found widespread use in the automotive industry. This substance is typically used if the viscosity of a building medium has to be changed [32].

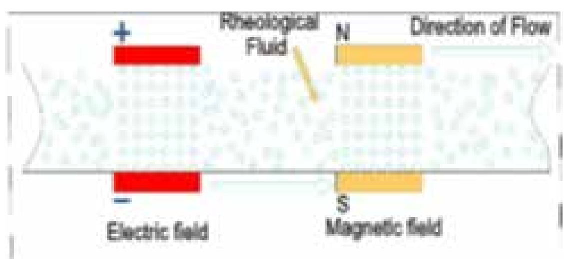


Figure 6. Rheological material

Thermo-responsive Material

These materials are polymers that radically change their physical characteristics when subjected to temperature variations (Fig. 7). This material is employed in vehicles and airplanes, and it is also used in thermostats. It experiences tiny to extremely substantial modifications that are continual in nature. They're also referred to as stimuli-sensitive materials [30, 33, 34].

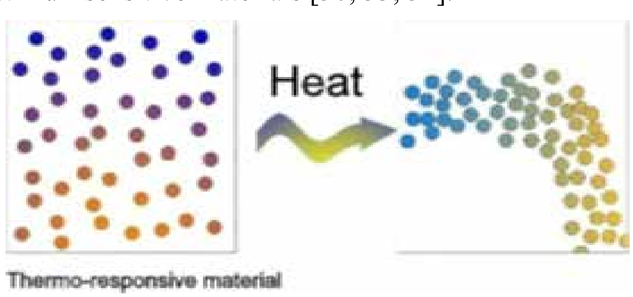


Figure 7. Thermo-responsive materials

Electrochromic Material

These are a necessary component of today's liquid crystal display systems. When an electric current is transmitted through such materials, its optical characteristics change. Fig. 8. These are also used in lithium-ion batteries. Redox response can also vary its colors if necessary. When a voltage is supplied, the ions pass through the separator and reach the outer layer. The layer becomes saturated and begins to reflect light, which causes it to become opaque or any other needed feature [35,36].

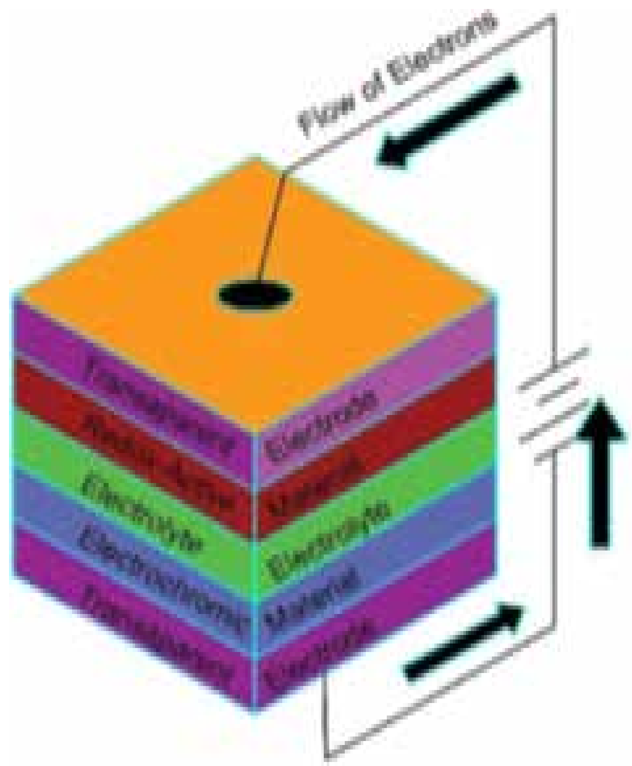


Figure 8. Electrochromic Materials

This subtitle encompasses a collection of materials whose reaction is to change colour in response to the effect of the outer media. Include the following supplies: Thermochromic, photochromic, piezochromic, electrochromic, solvatechromic, and carsolchromic materials are examples of thermochromic materials [37].

ADVANTAGES, DISADVANTAGES AND APPLICATIONS OF SMART MATERIALS

Table 1. Advantages, disadvantages and applications of smart materials

Name of Smart Material	Advantages	Disadvantages	Application
Piezoelectric Materials	Response at high frequencies [42] On the application of mechanical force, generate an electrical signal [47] Simple is the construction [48] High sensitivity and stability [109]	Working stroke is restricted to a few or ten micrometres, which restricts its use in or as actuators. [47] both wear and heat production difficult to produce The structure of inchworm piezoelectric is intricate. Static measures are not employed [109]	Used in electrical equipment like sensors and transducers Due to their high curie temperature, they are used at high temperatures [48]. precise micropositioning Auto power generator sensor for tyre pressure The knock sensor A piezo fuel injector
Magnetostrictive Materials	Incresed Energy Density Robustness from inside [45]	The degree of material complexity rises. There wasn't enough experimental proof identified. The complexity of the system is increased by magnetostrictive materials [45]. The reproducibility of experiments is insufficiently accurate [45].	Damper for tuned vibration absorption sensors mounted on the engine Harvesting energy [43, 31, 110]
Shape Memory Alloy	They exhibit flexible behaviour. extreme fatigue failure Life [49] increased damping capabilities High power Corrosion-proof [50]	unable to simply accept a job. Extremely Dense [42] After lengthy use, fluid becomes thick and needs to be replaced [46]. High-end fluids are pricey. It can be difficult for ferro particles to settle.	Buildings and automobiles [111, 112] Shock absorbers and vibration dampers Clutches Valve hydraulics [46] Anti-vibration device a layer of iron particles forming sealing issues Pollution of the environment [44]
Thermo-responsivematerials	When subjected to temperature changes, physical properties might change [55].	Costly	Vehicles, aeroplanes, and thermostats [56]
Electrochromic materials	When an electric current is applied, the optical characteristics change.	inadequate colour efficiency and longevity	Lithium ion batteries [36, 119] and liquid crystal display units
Fullerness	Nature is highly stable and flexible [30, 55].	Health and environmental consequences [55]	Corrosion resistance, fracture prevention, mechanical durability, and electrical appliances [41] are all important considerations.
Biomimetic materials	Strength, concealment, and water resistance [30,52]	Sensitivity to abrasion, poor abrasion resistance	Applications in biomedicine

Graphite Fibers	Tensile strength is excellent, and the coefficient of thermal expansion is low.	Machining weakens the GF and causes it to break when squeezed.	Satellites, Ships, and Aircraft [42]
Transparent Aluminum	High strength	Impurity reduction, micropore elimination, and grain boundary control.	defense application [53]
Optical fibers	Support for higher bandwidth substantial carrying capacity immunity to electromagnetic snooping and interference Flexible Cables made of optical fibre take up less room. Against corrosive substances [54]	Expanded transmitter and receiver capabilities It is unable to transport electrical current to power terminal devices. At greater optical powers, ineffective It is expensive to install.	Modern security systems for detecting intrusions [53] optical biosensors and optical chemical sensors. used as light guides in applications such as medicine and other fields, and to convey electricity utilising solar cells [54] Monitoring the health of structures, spectroscopy, and imaging optics
Smart Glass	Cost-effectively adjust the amount of heat and light [30, 55]	Initial cost is high	Automobiles and Buildings [31]

4.CHALLENGES AND LIMITATIONS ASSOCIATED WITH THE DEVELOPMENT OF ANY NEW SMART MATERIALS

Smart materials may be used to create affordable, environmentally friendly, and effective mechanical and building components. Despite all of these potential uses, these materials are not typically employed in building due to a few problems. The following list of fundamental problems has been compiled, along with where they could be resolved, when possible:

Using such expensive raw materials and processing them adds to the cost of the final product. But with large demand and frequent use in buildings, mass production might considerably lower the cost. Due to the effectiveness of such materials, the cost may decrease with savings. Less study has been done on this topic because these materials are still relatively new in construction. Therefore, practitioners who use these materials experience dread due to a lack of knowledge about them. This worry could be diminished by sound research and free access to it. It is clear that we are reluctant to use new tools when the ones we already have perform just fine. With widespread attention and the use of such information in public settings, this view may be altered. Because of their high cost and lack of study, such materials are used less frequently in actual projects. By paying attention to the points mentioned above, this issue may be resolved.

FUTURE SCOPE IN SMART MATERIALS

In the world of technology, smart materials are crucial to a variety of industries and fields. Recent research has shown that these materials' methodologies actively contribute to bettering product features and specifications by withstanding harsh environmental conditions as well as sudden changes in working environments thanks to their unique properties. Along with the chosen time frame (2017–2023).

This study demonstrated the critical significance of smart materials applications in several industries, including the textile sector, renewable engineering, biomedical engineering, and medical engineering. However, as shown in Fig. 12, there are really relatively few applications in the mechanical branch. Therefore, our study strongly urges more investigation in the two aforementioned sectors. On the other hand, the author suggests that in order to fully benefit from and utilise the capabilities of smart materials technology, new means need be found to connect it with other engineering departments, particularly mechanical engineering [51-56]

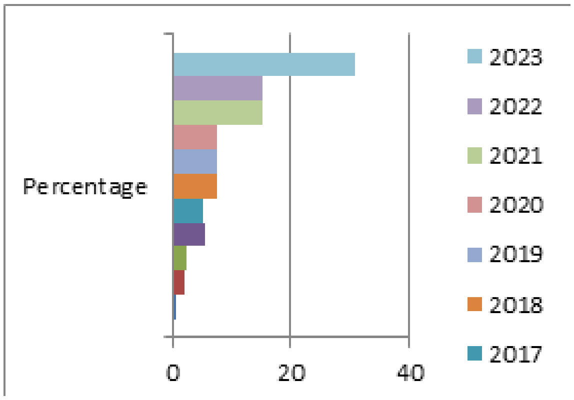


Figure 10. The percentage of smart materials technologies used through the chose period

These synthetic or diverse materials with special intelligence sense will be used by the industry stated in Fig. 1 and other possible industries in the future to attain sustainability [104]. In mechanical engineering, using smart materials can reduce energy use and CO2 emissions. Here are some of the possible scopes for future research:

- Advanced Synthesis Techniques: Exploring innovative methods for synthesizing smart materials with improved properties and functionalities.
- Integration in Construction: Investigating novel applications of smart materials in construction for enhanced structural performance, energy efficiency, and sustainability.
- Energy-Efficient Mechanical Systems: Developing smart materials and systems that minimize energy consumption in mechanical engineering applications, thereby reducing carbon emissions.
- Environmental Sensing and Monitoring: Utilizing smart materials for real-time environmental sensing and monitoring, with applications in pollution control, climate monitoring, and disaster resilience.
- Biomedical Applications: Expanding the use of smart materials in biomedical devices and therapies, including drug delivery systems, wearable health monitors, and prosthetics.

CONCLUSION

In conclusion, this review paper has provided a comprehensive overview of the diverse landscape of smart materials in mechanical engineering. Beginning with an engaging introduction, we embarked on a journey through the world of smart materials, emphasizing their significance in addressing contemporary technological challenges. The background section introduced smart materials and their key characteristics, setting the stage for a deeper exploration. We delved into various types of smart materials, from shape memory alloys to piezoelectric materials, highlighting their unique properties and immense potential for innovation. Advantages and disadvantages were discussed, underscoring the adaptability, efficiency, and cost-effectiveness of these materials, while acknowledging challenges related to scalability and integration. The heart of this paper was dedicated to exploring real-world applications of smart materials in mechanical engineering. Through case studies and examples, we demonstrated how these materials have transformed industries, from robotics and aerospace to automotive systems and biomedical devices. However, the journey of smart materials is not without its obstacles. We examined the challenges and restraints inherent in developing novel smart materials, acknowledging the need for cost-effective manufacturing, regulatory considerations, and ethical implications.

REFERENCES

1. Hayder M. Abbood,, Abdulsattar K. Al Ghanimi, “Smart Materials Technologies and Applications in Mechanical Engineering and Renewable Energies”, Journal of Advanced Research in Fluid Mechanics and Thermal Sciences, 64, Issue 2 (2019) 196-205, ISSN: 2289-7879
2. Pundru Srinivasa Rao. “Literature review of smart materials / actuators / sensors in the design of smart flexible life saving robots.” Int. J. Adv. Res. Sci. Eng. Technol. 3, no. 5 (2016): 2034–2040.
3. Gomaa, E.G., Badran, E.E., Mahmoud, M.A., and Saleh, A.M. “The use of smart materials in raising the efficiency of the performance of buildings.” International Journal of Application or Innovation in Engineering & Management 5, no. 10 (2016): 1-18.
4. S.K. Ghosh, “Self-healing Materials: Fundamentals, Design Strategies, and Applications,” Wiley- VCH, pp. 1–28, 2008, doi: 10.1002/9783527625376..
5. W.B. Spillman, J.S. Sirkis, P.T. Gardiner, Smart materials and structures: what are they?, Smart Mater. Struct.5

(3) (1996) 247–254, https://doi.org/10.1088/0964-1726/5/3/002.

6. S.-Y. Chen, S.-F. Chang, A Review of Smart Living Space Development in a Cloud Computing Network Environment, Comput.-Aided Des. Applic.6 (4) (2009) 513–527, https://doi.org/10.3722/cadaps.2009.513-527.

7. T.T. Soong, B.F. Spencer, Supplemental energy dissipation: state-of-the-art and state-of-the-practice, Eng. Struct. 24 (3) (2002) 243–259, https://doi.org/10.1016/S0141-0296(01)00092-X.

8. B.A. Mir, "Smart Materials and Their Applications in Civil Engineering: An Overview," International Journal of Civil Engineering and Construction Scienc, 4 (2) (2017) 11–20.

9. G. A. O. Davies, "Smart Material Structures: Modeling, Estimation and Control H.T. Banks, R.C. Smith and Y. Wang John Wiley and Sons, Baffins Lane, Chichester, West Sussex POI9 WD. 1996. 304pp. Illustrated. £55.," The Aeronautical Journal (1968), vol. 101, no. 1010, pp. 486–486, 1997, doi:10.1017/S000192400006588X..

10. V.C. Li, Y.M. Lim, Y.-W. Chan, Feasibility study of a passive smart self-healing cementitious composite, Compos.B Eng. 29 (6) (Nov. 1998) 819–827, https://doi.org/10.1016/S1359-8368(98)00034-1.

11. A.S.Y. Mohamed, Smart Materials Innovative Technologies in architecture; Towards Innovative design paradigm, Energy Procedia 115 (Jun. 2017) 139–154, https://doi.org/10.1016/j.egypro.2017.05.014.

12. C. S. Cai, W. Wu, S. Chen, and G. Voyiadjis, "Applications of Smart Materials in Structural Engineering," p. 71.

13. B. Robert, Smart materials: a review of recent developments, Assembly Automation 32 (1) (Jan. 2012) 3–7, https://doi.org/10.1108/ 01445151211198674.

14. S. S. Aher, A. Desarda, J. A. Shelke, and M. Chaudhari, "A REVIEW ON SMART MATERIALS: FUTURE POTENTIALS IN ENGINEERING," vol. 4, no. 10, pp. 7–16,Oct. 2015.

15. D. M. Addington, D.L. Schodek, Smart materials and new technologies: for the architecture and design professions, Architectural Press, Amsterdam; Boston, 2005.

16. B. Robert, Smart materials: a review of capabilities and applications, Assembly Automation 34 (1) (Jan. 2014) 16–22, https://doi.org/10.1108/AA- 10-2013-094.

17. R. Sabo, A. Yermakov, C. T. Law, and R. Elhajjar, "Nanocellulose-Enabled Electronics, Energy Harvesting Devices, Smart Materials and Sensors: A Review," j renew mater, vol. 4, no. 5, pp. 297–312, Oct. 2016, doi: 10.7569/JRM.2016.634114..

18. S. S. Mathurkar, "International Journal of Soft Computing and Engineering," vol. 2, no. 4, p. 3, 2013..

19. S. Coyle, Y. Wu, K.-T. Lau, D. De Rossi, G. Wallace, D. Diamond, Smart Nanotextiles: A Review of Materials and Applications, MRS Bull. 32 (5) (2007) 434–442, https://doi.org/10.1557/mrs2007.67.

20. J. Genzer, K. Efimenko, Recent developments in superhydrophobic surfaces and their relevance to marine fouling: a review, Biofouling 22 (5) (Jan. 2006) 339–360, https://doi.org/10.1080/08927010600980223.

21. V. Giurgiutiu, Review of Smart-Materials Actuation Solutions for Aeroelastic and Vibration Control, J. Intell. Mater. Syst. Struct. 11 (7) (Jul. 2000) 525–544, https://doi.org/10.1106/HYTV-NC7R-BCMM-W3CH.

22. R. C. Smith, Smart material systems: model development. Philadelphia: Society for Industrial and Applied Mathematics, 2005..

23. Ephrahim Garcia, "Smart structures and actuators: past, present, and future," Jul. 2002, vol. 4698, [Online]. Available: https://doi.org/10.1117/12.475054..

24. P.-F. Gobin, G. Gutnin, M. Morin, M. Salvia, J. Tatibouet, Smart Materials: A Future for Composites, J. Intell. Mater. Syst. Struct. 7 (3) (May 1996) 353–357, https://doi.org/10.1177/1045389X9600700318.

25. D. Roy, J.N. Cambre, B.S. Sumerlin, Future perspectives and recent advances in stimuli-responsive materials, Prog. Polym.Sci. 35 (1–2) (Jan. 2010) 278–301, https://doi.org/10.1016/j.progpolymsci.2009.10.008.

26. M Balasubramanian et al 2021, "Application of shape memory alloys in engineering – A review"J. Phys.: Conf. Ser. 2054 012078

27. B. R. Shreyas and N. Arunkumar."Industrial Applications of Smart Materials – An Overview."

[28. L.J. Garner, L.N. Wilson, D.C. Lagoudas, O.K. Rediniotis, Development of a shape memory alloy actuated biomimetic vehicle, Smart Mater.Struct.9 (5) (Sep. 2000) 673–683, https://doi.org/10.1088/0964-1726/9/5/312.

29. H. A. Sodano, D. J. Inman, and G. Park, "A Review of Power Harvesting from Vibration Using Piezoelectric

Materials," shock vib digest, vol. 36, no. 3, pp. 197–205, May 2004, doi: 10.1177/0583102404043275.

30. Mukherjee, Deepmala, P. Srivastava et al., Application of smart materials in civil engineering: A review, Materials Today: Proceedings, https://doi.org/10.1016/j.matpr.2021.03.304

31. Qinghua, Cao, Chen Dingfang, Li Chuan, Lu Quanguo, and ZengYulu. "A review of the magnetomechanicalmodeling of magnetostriction materials." In Joint International Conference on Pervasive Computing and the Networked World, pp. 1-7. Springer, Cham, 2013.

32. A.G. Olabi, A. Grunwald, Design and application of magnetostrictive materials, Mater. Des. 29 (2) (2008) 469–483.

33. D. Damjanovic, R.E. Newnham, Electrostrictive and Piezoelectric Materials for Actuator Applications, J. Intell. Mater. Syst. Struct. 3 (2) (Apr. 1992) 190–208, https://doi.org/10.1177/1045389X9200300201.

34. K. Uchino, "Electrostrictive actuators: materials and applications.," Bulletin of the American Ceramic Society, vol. 65, no. 4, pp. 647–652, 1986.

35. R.J. Mortimer, Electrochromic materials, Chem. Soc. Rev. 26 (3) (1997) 147– 156.

36. R.J. Mortimer, Electrochromic materials, Annu. Rev. Mater. Res. 41 (1) (2011) 241–268.

37. Suhag, N., and S. Singh. "Types of chromism& its applications in fashion & textile designing."International Journal of Enhanced Research in Science, Technology & Engineering 4, (2015).

38. J.A. Harvey, Smart materials, Kirk-Othmer Encycl. Chem. Technol. 1 (Dec. 2000), https://doi.org/10.1002/0471238961.1913011808011822.a01.

39. J. Lee, S. Mahendra, P.J.J. Alvarez, Nanomaterials in the Construction Industry: A Review of Their Applications and Environmental Health and Safety Considerations, ACS Nano 4 (7) (Jul. 2010) 3580–3590, https://doi.org/10.1021/nn100866w.

40. J. Aizenberg, P. Fratzl, Biological and biomimetic materials, Adv. Mater. 21 (4) (2009) 387–388.

41. A. Al-Tabbaa, B. Lark, K. Paine, T. Jefferson, C. Litina, D. Gardner, T. Embley, Biomimetic cementitious construction materials for next-generation infrastructure, Proceedings of the Institution of Civil Engineers – Smart Infrastructure and Construction.

42. S. Wang, W. Rong, L. Wang, H. Xie, L. Sun, J.K. Mills, A survey of piezoelectric actuators with long working stroke in recent years: classifications, principles, connections and distinctions, Mech. Syst. Signal Process. 123 (2019) 591–605, https://doi.org/10.1016/j.ymssp.2019.01.033.

43. F. Narita, M. Fox, A review on piezoelectric, magnetostrictive, and magnetoelectric materials and device technologies for energy harvesting applications, Adv. Eng. Mater. 20 (2018) 1–22, https://doi.org/10.1002/adem.201700743.

44. H. Li, C. Yu, R. Chen, J. Li, J. Li, Novel ionic liquid-type Gemini surfactants: synthesis, surface property and antimicrobial activity, Colloids Surf. A Physicochem.Eng. Asp.395 (2012) 116–124, https://doi.org/10.1016/j.colsurfa.2011.12.014.

45. V. Apicella, C.S. Clemente, D. Davino, D. Leone, C. Visone, Review of modeling and control of magnetostrictive actuators, Actuators 8 (2019) 1–30, https:// doi.org/10.3390/act8020045.

46. C.J. Lin, C.Y. Lee, Y. Liu, Vibration control design for a plate structure with lectrorheological ATVA using interval Type-2 fuzzy system, Appl. Sci. 7 (2017), https://doi.org/10.3390/app7070707.

47. J. Li, H. Huang, T. Morita, Stepping piezoelectric actuators with large working stroke for nano-positioning systems: a review, Sens. Actuat., A Phys. 292 (2019) 39–51, https://doi.org/10.1016/j.sna.2019.04.006.

48. T. Zheng, J. Wu, D. Xiao, J. Zhu, Recent development in lead-free perovskite piezoelectric bulk materials, Prog. Mater.Sci. 98 (2018) 552–624, https://doi.org/10.1016/j.pmatsci.2018.06.002.

49. A. Phys, Energy harvesting from structural vibrations of magnetic shape memory alloys, 103905 (2017). https://doi.org/10.1063/1.4978258.

50. K. Alaneme, E. Okotete, J. Anaele, Structural vibration mitigation – a concise review of the capabilities and applications of Cu and Fe based shape memory alloys in civil structures, J. Build. Eng. 22 (2018), https://doi.org/10.1016/j.jobe.2018.11.014.

51. K. Kanayo, E. Anita, J. Uchenna, Structural vibration mitigation – a concise review of the capabilities and applications of Cu and Fe based shape memory alloys in civil structures, 22 (2019) 22–32.

52. N.G. Garafolo, G.R. Mchugh, Mitigation of flutter vibration using embedded shape memory alloys, 76 (2018) 592–605.

53. P. Nnamchi, A. Younes, S. González, Intermetallics A review on shape memory metallic alloys and their critical stress for twinning, 105 (2019) 61–78

54. X. Dong, C. Niu, M. Qi, Enhancement of electrorheological performance of electrorheological elastomers by improving, (2016) 6806–6815. https://doi. org/10.1039/c6tc01447j.

55. S. Bahl, H. Nagar, I. Singh et al., Smart materials types, properties and applications: A review, Materials Today: Proceedings, https://doi.org/10.1016/j. matpr.2020.04.505

56. Y. Agarwal, B. Balaji, R. Gupta, J. Lyles, M. Wei, and T. Weng, "Occupancydriven energy management for smart building automation," Proceedings of the 2nd ACM Workshop on Embedded Sensing Systems for Energy-Efficiency in Building.Association for Computing Machinery, Zurich, Switzerland, pp. 1– 6, 2010, [Online]. Available: https://doi. org/10.1145/1878431.1878433.

Design and Fabrication of Aqua Silencer with Monitoring Capabilities

Azlan Hoona
✉ azlan.hoona99@gmail.com

Fardeen Hodekar
✉ fardeenhodekar123@gmail.com

Mohammad Talha Borkar
✉ mohdtalhaborkar12@gmail.com

Shashikant Goilkar
✉ shashikant.goilkar@famt.ac.in

Department of Mechanical Engineering
Finolex Academy of Management and Technology
Ratnagiri, Maharashtra

ABSTRACT

This research paper presents the design, fabrication, and evaluation of an innovative aqua silencer equipped with advanced monitoring capabilities. Traditional internal combustion engine exhaust systems contribute to environmental pollution through the emission of harmful gases and noise. The proposed aqua silencer aims to address these issues by utilizing water as a medium to attenuate exhaust noise and suppress emissions. Additionally, the integration of monitoring capabilities enhances the functionality of the aqua silencer by providing real-time data on exhaust gas composition and noise levels. The design phase involved optimizing the internal geometry of the aqua silencer to maximize noise reduction and minimize back pressure. The fabrication process utilized corrosion-resistant materials to ensure long-term performance in aquatic environments. Experimental testing was conducted using a prototype aqua silencer installed on a gasoline engine. Results demonstrated a substantial reduction in exhaust noise and a noticeable decrease in emission levels. Furthermore, the incorporation of monitoring sensors allowed for continuous data collection and analysis of exhaust gases. This real-time monitoring facilitated the identification of emission trends and provided insights for potential engine performance enhancements. The collected data were analysed using statistical methods, revealing a correlation between noise reduction and exhaust gas composition. In conclusion, this research introduces a novel approach to exhaust system design through the integration of an aqua silencer with monitoring capabilities. The combination of noise reduction, emissions suppression, and real-time data analysis highlights the potential for improved environmental and engine performance. As society places increasing importance on sustainable technologies, the aqua silencer presents a promising solution for the automotive industry and beyond.

KEYWORDS *: Aqua silencer, Real time monitoring, Perforated tube, Air pollution, activated charcoal, Lime water.*

INTRODUCTION

In an era marked by heightened environmental concerns and the pursuit of sustainable technologies, the automotive industry faces an imperative to reinvent its conventional practices. One of the significant challenges inherent in internal combustion engines is the dual problem of noise pollution and harmful emissions. The release of exhaust gases not only contributes to air pollution but also generates noise that disrupts the acoustic environment. As regulatory bodies worldwide tighten emission standards and noise regulations, there arises a need for innovative solutions that can address both issues simultaneously.

Traditional internal combustion engine exhaust systems contribute to environmental pollution through the emission of harmful gases and noise. This research explores the design, fabrication, and evaluation of an innovative aqua silencer equipped with advanced monitoring capabilities to address these concerns. Aqua silencers utilize water as a medium to attenuate exhaust noise and suppress emissions. The integration of monitoring capabilities enhances the functionality of the aqua silencer by providing real-time data on exhaust gas composition and noise levels.

Numerous studies have underscored the adverse environmental and health implications of conventional internal combustion engine exhaust systems. Research by [2] highlighted the urgent need for novel exhaust system solutions that simultaneously mitigate noise and emissions. Further investigations by [3] demonstrated the potential of alternative attenuation mediums, such as water-based systems, to address these issues effectively. Inquiries into noise control mechanisms by [4] have traced the evolution of exhaust noise reduction techniques. The chronological progression from rudimentary mufflers to more intricate resonators and baffles illuminates the persistent pursuit of quieter engine operations. Additionally, pioneering work by [5] delves into the symbiotic relationship between noise reduction and emission control, showcasing the potential for holistic solutions. Advancements in monitoring technologies have also left a discernible mark on exhaust system research. The integration of real-time sensors, as explored by [6] has ushered in an era of data-driven analysis for exhaust system performance. This integration enables dynamic adjustments to optimize engine efficiency while complying with emission standards.

While existing literature offers valuable insights into isolated aspects of exhaust system enhancement, a comprehensive approach that synergistically integrates noise reduction, emission control, and real-time monitoring capabilities remains underexplored. This research gap signals the need for an in-depth exploration into the potential of Aqua Silencers with integrated monitoring capabilities as a multifaceted solution for modern exhaust system challenges.

This research aims to develop and evaluate a sensor-equipped aqua silencer to address the challenge of noise reduction and emission control in internal combustion engines. The specific objectives include:

1. Design and fabricate a functional prototype aqua silencer with optimized internal geometry for noise reduction and minimal back pressure.
2. Integrate real-time monitoring sensors within the aqua silencer to measure exhaust gas composition, temperature, and noise levels.
3. Experimentally evaluate the effectiveness of the sensor-equipped aqua silencer in reducing noise and emissions from a gasoline engine.
4. Analyse the collected data to understand the correlation between noise reduction and exhaust gas composition.

By achieving these objectives, this research seeks to contribute to the development of sustainable and environmentally friendly automotive technologies.

AQUA SILENCER TECHNOLOGY WORKING PRINCIPLE

The working principle of Aqua Silencers with integrated monitoring capabilities revolves around the synergistic utilization of water-based noise attenuation, emission suppression mechanisms, and real-time sensor technology. The Aqua Silencer is designed to reduce exhaust noise and suppress harmful emissions by leveraging water injection as an innovative mechanism. [9] As exhaust gases pass through the Aqua Silencer, water is introduced into the exhaust stream. The water serves multiple functions: it absorbs sound waves, cools theexhaust gases, and chemically interacts with certain components of the emissions. This interaction aids in the reduction of pollutants such as nitrogen oxides (NOx) and hydrocarbons (HC). The water's cooling effect can also assist in lowering the overall exhaust gas temperature. [7] The integration of real-time monitoring sensors further enhances the Aqua Silencer's functionality. These sensors continuously measure parameters such as exhaust gas composition, temperature, and noise levels. The collected data is transmitted to a control unit, providing real-time feedback on the performance of the Aqua Silencer and the engine. This information enables adjustments to optimize the Aqua Silencer's efficiency and engine performance, ensuring the desired balance between noise reduction, emission suppression, and power output.[10]

To anticipate potential challenges during the fabrication of an Aqua Silencer and its corresponding test rig, a comprehensive 3D solid model of the entire test setup was meticulously designed, as depicted in Figure 1.

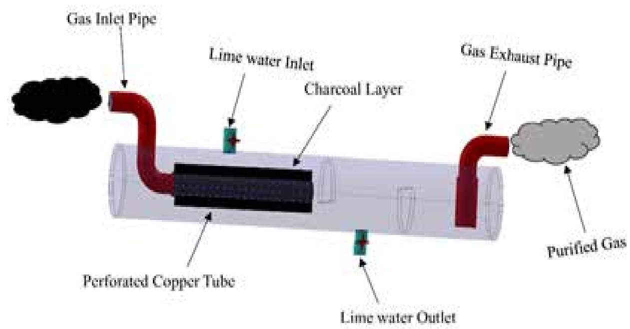


Fig 1. 3D Model of Aqua Silencer [1]

Addressing Water Contamination in Aqua Silencers: Control Strategies

In the context of Aqua Silencers, water contamination arises due to the dissolution of gases present in the exhaust emissions, a concern previously discussed. These gases, upon interaction with water, form compounds such as carbonates and acids including carbonic, sulfuric, and nitrous acids. Further exacerbating the issue, petroleum derivatives containing phenolic compounds introduce a pronounced odorous element. The incorporation of sulphur compounds into the water results in the formation of hydrogen sulphide, characterized by an offensive rotten egg aroma. Managing these challenges is paramount to curtailing water pollution. In response, two discerning methods emerge as potential solutions:

Lime Water Wash Method: A first approach entails the implementation of the lime water wash method. By introducing lime water into the Aqua Silencer's water reservoir, a chemical reaction occurs wherein the dissolved acidic gases react with the alkaline lime solution. This reaction leads to the formation of harmless compounds that can be readily discharged without detrimental environmental consequences. The lime water wash technique thus acts as a buffer against the generation of acidic pollutants, effectively minimizing water pollution and its attendant adverse effects.[10]

Limitations of lime water wash method:

- Amount of neutralization capacity is limited
- It is very difficult to handle
- Bridging and form are formed
- It is expensive
- Regeneration is possible
- Lime in any form it is difficult to handling.[10]

Absorption Process

The second avenue of mitigation involves the adoption of an adsorption process. This entails the utilization of adsorbent materials within the Aqua Silencer that possess an inherent affinity for the noxious gases and phenolic compounds. As the polluted water interacts with the adsorbent, these undesirable substances are selectively captured and retained, leaving the water cleansed and less susceptible to noxious Odors and contamination. The adsorption process serves as an efficient and versatile mechanism for addressing water pollution arising from dissolved exhaust gases and petroleum derivatives. In embracing these methodologies, the Aqua Silencer not only effectively addresses the challenges posed by water contamination but also aligns with the overarching objective of advancing sustainable and environmentally-conscious exhaust system solutions.

Monitored real-time exhaust gas composition, temperature, and noise levels using integrated monitoring sensors during each trial.

Advantages of absorption process

- It enhances the coagulation capability of the treatment.
- Its application reduces the need for chlorine.
- An excess amount of activated carbon does not pose harm.
- The treatment procedure is straightforward and requires minimal expertise.
- It exhibits a high efficiency in eliminating colour, odour, and taste.
- It possesses exceptional properties for attracting gases.[10]

Consequences of Exhaust Gases on Lime Water

Action of dissolved SO_2 Upon mixing SOx in water, it results in the formation of various compounds such as SO_2 SO_3, SO_4, and H_2SO_4, namely sulfuric acid (H_2SO_3).

This leads to the generation of hydrogen sulphide, characterized by its unpleasant odour resembling rotten eggs, along with acidification and corrosion of metals.

Action of dissolved CO_2 Dissolved carbon dioxide gives rise to bicarbonate at lower pH levels and carbonates at higher pH levels. Calcium carbonate will precipitate when carbon dioxide present in exhaust gas and in contact with lime water.

Effect of dissolved NOx the byproduct of combustion, consists of nitrogen oxides, which are known for their unpleasant nature. Nitrogen is absorbed to a greater degree by water.[7]

Reactions

Calcium sulphate is formed as a result of removing SO_2 gas from the flue gases.

$Ca(OH)_2 + SO_2$........ $CaSO_3 + H_2O$

Neutralizes any acid present in water

2HCL + $Ca(OH)_2$..........$Cacl_2$+ $(2H_2)$ H_2SO_4 + $Ca(OH)_2$...........

$CaSo_4 + 2H_20$

Precipitates bicarbonate as calcium carbonate

$CO_2 + Ca(OH)_2$ .... $CaCO_2 + 2H_2O$

Precipitates bicarbonate as calcium carbonate

$Ca(HCO_3)_2 + 2Ca(OH)_2$......... $2CaCO_2 + 2H_2O$

Converts bicarbonate ions (Like $NaHCO_3$,

$KHCO_3$ etc.) into carbonates.

$NaHCO_3 + Ca(OH)_2$............ $CaCO_3 + H_2O + Na_2CO_3$ [7].

Components and Explanation

Inlet Pipe: The entry point for exhaust gases into the Aqua Silencer.

Perforated Tube: Contains multiple small holes to disperse exhaust gases, initiating noise reduction.

Water Chamber: Where controlled water injection occurs, leading to the dissolution of exhaust gases and the formation of compounds.

Outlet Pipe: Releases treated exhaust gases into the environment.

Mics-6814 Gas Sensor: Detects gases such as carbon monoxide (CO), nitrogen dioxide (NO_2), and ammonia (NH_3), providing real-time emission composition insights.

DHT22 Temperature and Humidity Sensor: Measures ambient temperature and humidity, contributing to exhaust gas analysis.

Control Unit: Processes and analyses data collected from sensors, enabling informed decision-making for optimization and refinement.

Sound Absorbing Material: Lining the interior of the Aqua Silencer to further dampen exhaust noise.

Catalytic Converter: Facilitates the breakdown of pollutants in the water, enhancing emission control.

DESIGN CONSIDERATIONS FOR IMPLEMENTING MONITORING CAPABILITIES

The successful integration of monitoring sensors within Aqua Silencers, such as the Mics-6814 gas sensor and the DHT22 Temperature and Humidity sensor, represents a pivotal advancement in exhaust system technology. These sensors play a critical role in enabling real-time data acquisition, offering insights into exhaust gas composition, temperature, and noise levels. The Mics-6814 gas sensor detects various gases, including carbon monoxide (CO), nitrogen dioxide (NO2), and ammonia (NH3), providing a comprehensive overview of emission profiles. Additionally, the DHT22 Temperature and Humidity sensor accurately measures ambient conditions, aiding in the analysis of exhaust gas behaviour. [6] The implementation process involves strategically positioning these sensors at key points within the Aqua Silencer assembly to capture accurate and representative readings. This positioning ensures that data collection is reflective of the exhaust gases' journey through the silencer, facilitating a comprehensive understanding of emission dynamics and noise characteristics. Moreover, the monitoring sensors are meticulously calibrated to ensure precision and reliability in data measurement. The collected data is transmitted to a central control unit, where it is processed, analysed, and presented in a user-friendly format. This real-time information empowers operators and engineers to make informed decisions regarding engine performance optimization, emission control, and exhaust system refinement. The incorporation of monitoring sensors, such as the Mics-6814 gas sensor and the DHT22 Temperature and Humidity sensor, not only elevates the efficacy of Aqua Silencers in noise reduction and emission suppression but also contributes to the broader goals of sustainable automotive technologies by providing data-driven insights for continuous improvement.[9]

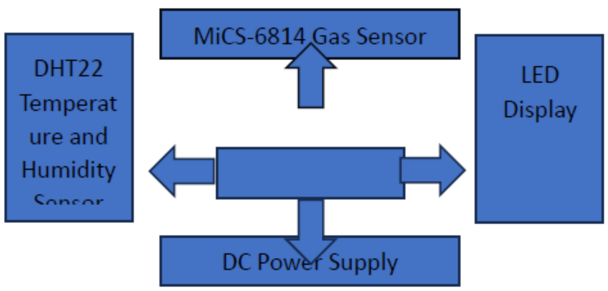


Fig 2. Block Diagram of Monitoring System.

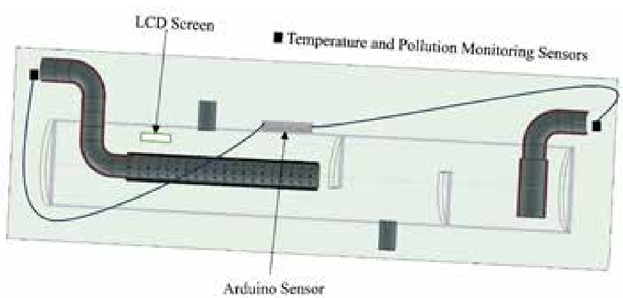


Fig 3. Test Setup and Sensor Implementation [11]

EFFECTIVENESS OF THE AQUA SILENCER

The integration of monitoring capabilities within Aqua Silencers offers a host of advantages that reverberate across the realms of noise reduction, emission control, and engine performance optimization. The foremost benefit lies in their unparalleled noise attenuation ability, contributing to quieter and more environmentally harmonious urban environments. Moreover, the real-time monitoring sensors, such as the Mics-6814 gas sensor and the DHT22 Temperature and Humidity sensor, provide immediate access to critical data, enabling operators to fine-tune engine parameters for optimal performance and reduced emissions. This data-driven approach translates into substantial gains in fuel efficiency and exhaust gas cleanliness, thereby aligning with the ethos of sustainable automotive practices. Aqua Silencers also demonstrate compatibility with a variety of internal combustion engine types, underscoring their versatility and potential for widespread adoption. The integration of these advanced technologies not only addresses contemporary exhaust system challenges but also resonates with a vision of a cleaner, quieter, and more efficient automotive landscape. The merits of Aqua Silencers with integrated monitoring transcend mere noise reduction and extend into the realm of holistic and forward-thinking exhaust system engineering.

CONCLUSION

This research work has explored the integration of monitoring capabilities into Aqua Silencer systems as a means to address the challenges of reducing engine emissions and noise pollution. Through a comprehensive investigation and conceptual framework development, we have laid the groundwork for designing and implementing sensor-equipped Aqua Silencers. By considering material selection, design optimization, and the development of prototypes, demonstrating the feasibility of enhancing Aqua Silencer technology with real-time monitoring capabilities. Through implementation, testing, and performance evaluation, we have shown that sensor-equipped Aqua Silencers have the potential to effectively reduce exhaust emissions and mitigate noise while providing valuable data for environmental monitoring and analysis. Furthermore, our discussion on the effectiveness and limitations of the monitoring system highlights areas for further research and improvement. Looking ahead, the future of Aqua Silencer technology lies in continued innovation and collaboration to develop advanced monitoring solutions that contribute to environmental sustainability.

REFERENCES

1. S. S. Goilkar, Design and Development of a Variable Damping Device for Vibration Control with Electrorheological (ER) Fluid, Adv. Intelligent Systems Research 137 (2016) 127–133.
2. Nickischer, An Environmental Impacts of Internal Combustion Engines and Electric Battery Vehicles. D.U. Quark, 4 (2) (2020) 21-31

3. I. S. Anufriev, Review of water/steam addition in liquid-fuel combustion systems for NOx reduction: Waste-to-energy trends, Renewable and. Sustainable Energy Reviews. 138 (2021) 110665

4. Patel, Murlidhar & Sen, Prakash & Sahu, Gopal. Review on Noise Sources and Methods of Reduction of Noise in Diesel Engines. 4 (2015) 601-607

5. Waleed Majeed, Reducing Exhaust Gas Emissions of Stationary Diesel Engines Using Water Bath, IOP Conf. Ser.: Mater. Sci. Eng. 518 (2019) 032019

6. Choodarathnakara A L, Punitha S, Vinutha, Shwetha B D, Abhishek H J, Sinchana G S, Real time IoT based air and noise pollution monitoring system. 8(3) (2019) 425-435

7. Omkar Mali, Pravin Shinde, Shivanand Patil, Akash Masal, Arunkumar Ravi, Prof. P.V. Kadam, Prof.V.P. Patil Research Paper on Aqua Silencer, International Research Journal of Engineering and Technology 05 (04) (2018) 743-745.

8. Mr. Sagar B. S, Prakash Hullur, Sangappa Ankush, Vikram raj Kannolli, Vinayak Rayakar. “Review Paper on Aqua Silencer. IJARIIE-ISSN(O)- (5) (2) (2019) 2395-4396.

9. Jayapal, Cynthia & M N, Saroja & Sultana, Parveen & Senthil J, IoT-Based Real Time Air Pollution Monitoring System. International Journal of Grid and High-Performance Computing. 11. (2019). 28-41.

10. Jothi Thirumal ‘Noise Control System by using Aqua Silencer. ISSN 2249-0019 (5) (2) (2015) 211-221.

11. Goilkar, Shashikant S. and Hirani, Harish (2009)’Design and Development of a Test Setup for Online Wear Monitoring of Mechanical Face Seals Using a Torque Sensor’, Tribology Transactions,52:1,47 — 58

Optimization of Micro-Drilling Machining Parameters in CFRP-Ti6Al4V Stack Composite using Artificial Neural Network

Swanand Joshi
✉ swanand.joshi@vpmmpcoe.org

Hrishikesh Bhave
✉ hrishikesh.bhave@vpmmpcoe.org

Rahul Kundiya
✉ rahul.kundiya@vpmmpcoe.org

Pranav Sawant
✉ pranav.sawant@vpmmpcoe.org

Department of Mechanical Engineering
VPM's MPCOE
Velneshwar, Maharashtra

ABSTRACT

This study focuses on optimizing the mechanical micro-drilling process for CFRP-Ti6Al4V stack composites, crucial in aerospace applications. These hybrid composites, featuring metal and CFRP layers, are extensively used in high-performance aircraft engines. This paper introduces a methodology for identifying optimal machining parameters to minimize hole taper, radial overcut, and delamination factor by incorporating Artificial Neural Network (ANN). The study validates the ANN's predictive and optimization capabilities through a practical machining experiment involving micro-drilling of CFRP-Ti6Al4V stack composite. A feed-forward neural network is constructed using data collected from the micro-drilling process, and Google Colab and Jupyter Notebook are employed for model training and testing. The results predicted by the ANN exhibit strong agreement with experimental values. Furthermore, the neural network model is leveraged to determine the machining parameters that lead to minimal output parameters. The analysis affirms that the ANN approach effectively predicts optimal machining parameters. The developed ANN model, utilizing a Sequential architecture with Relu activation, demonstrates superior predictive accuracy for critical output parameters (R-squared values: 0.9521, 0.9824, 0.9236). The study contributes to advancing the understanding of machining parameters, providing an efficient tool for optimizing micro-drilling processes and enhancing hole quality in aerospace manufacturing.

KEYWORDS : *CFRP-Ti6Al4V, Micro drilling, Artificial neural network, Radial overcut, Delamination.*

INTRODUCTION

CFRP-Ti6Al4V stack composites are widely used in aerospace to make engine parts such nacelles, wing panels, and cowlings. These composites, which range in thickness from 0.8 to 1.25 mm, are used in high-performance engines used in aeroplanes such as the Airbus A320 and 757 Dreamliner. Metal alloys have problems that are addressed by the combination of metal and composites, which increases durability and lowers the need for repairs[1-3]. Using a peck drilling cycle, mechanical micro-drilling produces microscopic holes as small as 50 µm in diameter. Because tiny devices are being used in more and more industries, such as electronics, medicine, and aeronautics, this approach is essential. [4, 5, 14 -17]

The low machinability of hybrid composite stacks makes it difficult to drill millions of holes in them. Severe hole damage caused by delamination and Ti burrs results in rejected components and higher machining expenses. Two important causes are found to be inefficient cutting settings and tool wear [1, 6, 7]. There are two cutting sequences used in the mechanical micro-drilling of CFRP-Ti6Al4V stacks: drilling from CFRP/Ti6Al4V and drilling to Ti6Al4V/CFRP. The drilling sequence for CFRP-Ti alloy is thought to be reasonable and efficient at reducing hole damage. By decreasing workpiece dynamics, the bottom Ti alloy minimises exit delamination damage. [1, 2, 6-8, 10-12]

The optimisation of the mechanical micro-drilling technique for CFRP-Ti6Al4V stack composite has been studied by R. Kundiya et al. They examined the impacts of feed rate, spindle speed, and MQL flow rate on three critical output parameters: hole taper, delamination factor, and radial overcut. They did this by using central composite design (CCD) and response surface methodology (RSM) for experimental design. Through twenty laboriously laborious tests, the study created a mathematical model that demonstrated the relationships between input machining parameters and output variables. It's interesting to note that spindle speed was shown to have a considerable impact on all three output qualities. [13, 14] .

In lieu of more traditional experimental research, this paper promotes the use of artificial neural network (ANN) modelling and optimisation as a time- and money-efficient method. The suggested method, which minimises output variables such hole taper, radial overcut, and delamination factor by focusing on machining parameters during micro drilling, is described in detail in the following sections. The experimental dataset from our previous study is provided in Section 2, and the development and adequacy of the suggested ANN are explained in Section 3. Section 4 provides an overview of the results and discussions, and Section 5 brings the study to a close.

EXPERIMENTAL DATASET

The experimental work of R. Kundiya et al., which focused on micro-drilling a CFRP-Ti6Al4V Stack composite, provided the dataset used in this study. The trials were designed using the five-level Central Composite Design (CCD) method of Response Surface Methodology (RSM), as Table 1 illustrates. The responses included delamination factor, radial overcut, and hole taper. The primary machining parameters included cutting spindle speed (v), feed rate (f), and MQL flow rate. [13].

The tool was made of TiN-coated tungsten carbide (WC), with a 140° point angle and a micro-drill diameter of 0.4mm. Hole diameters were measured using an ALICONA Infinite Focus optical microscope to calculate the delamination variable, taper off, and radially overcut. Figure 1 shows the SMD10B CNC microdrilling machine. The trials were carried out using this equipment, which includes an aerostatic spindle for adjusting speed and Epoxy glue for stacking CFRP and Ti6Al4V.

This dataset, extracted from Table 1, served as the basis for training and validating the proposed Artificial Neural Network (ANN) model. The training dataset comprised 16 values, with 4 reserved for validation. Google Colab - Jupyter Notebook was employed for modeling and training.

Table 1. Experimental Datasets [13]

Run	Factor 1	Factor 2	Factor 3	Response 1	Response 2	Response 3
	A: Spindle speed RPM	B: Feed rate mm/min	C: MQL flow rate ml/hr	Radial overcut	Delamination factor	Hole taper
2	40,000	1.2	150	28.24	1.0429	1.025
3	40,000	1.2	300	11.13	1.1374	0.215
4	35,000	1.45	98.8655	2.36	1.0421	0.456
5	35,000	1.45	225	19.56	1.0031	0.689

ARTIFICIAL NEURAL NETWORK

Predictive models, especially artificial neural networks (ANNs), are valuable tools for exploring the impact of input parameters on machining processes [18, 20 - 22]. In this study, Google colab and Jupyter Notebook was utilized to formulate ANNs. Various models were designed and evaluated based on criteria such as MAPE and R values. The Levenberg-Marquardt (LM) algorithm, known for its efficiency, was employed for training [19-21].

In our study, we used the Sequential model with the Relu activation function for Artificial Neural Network (ANN) modeling. The Sequential model simplifies layer-by-layer neural network creation for easy implementation. The Relu activation function was chosen for its effectiveness in capturing complex nonlinear patterns in the data, aligning with modern practices in neural network architectures for machining parameter optimization. The selected network architecture featured a feed forward neural network with a single hidden layer of 4 neurons, resulting in a structure of 3-4-3. This configuration demonstrated the lowest mean absolute prediction error of 7.144. Regression coefficient value for hole taper, radial overcut, and delamination factor in the validation dataset were 0.9521, 0.9824, and 0.9236 respectively, indicating a robust correlation between experimental and network outputs.

Fig. 1. SMD10B CNC micro-drilling machine experimental data

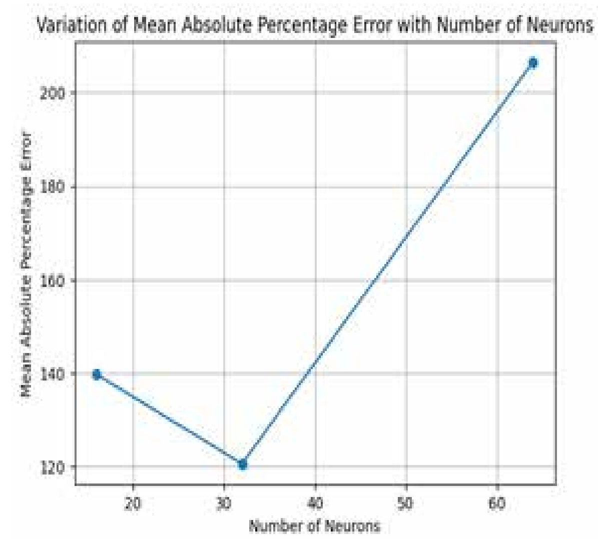


Fig. 2. Variation of MAPE in prediction with number of neurons

Figure 2 depicts a nonlinear relationship between the number of neurons and the Mean Absolute Percentage Error (MAPE). The MAPE lowers up to 34 neurons, showing higher model performance and lower prediction errors. However, the diagram indicates a linear increase in MAPE beyond 34 neurons, implying that increasing the complexity of the neural network architecture beyond a certain point may result in over fitting or decreasing returns. This highlights the significance of achieving an appropriate balance in neural network architecture in order to get the highest predicting performance.

Table 2. Verification of the developed model with

Experimental Taper	Predicted Taper	Experimental Radial Overcut	Predicted Radial Overcut	Experimental Delamination Factor	Predicted Delamination Factor
21.500	25.718	3.45	11.565	1.0064	0.959507
3.069	18.407	0.11	7.843	1.0317	0.079073
30.990	14.512	11.56	7.170	1.0079	0.467775
58.500	23.757	28.24	14.83	1.0429	1.758826

Table 2 shows The ANN model demonstrates good predictive performance. The ANN model slightly different predicts Taper, Radial Overcut, and Delamination Factor with low MAPE values and Regression coefficient values, demonstrating strong correlations and effective representation of machining parameter variations. Overall, the model fits well, providing accurate predictions for the specified parameters

Fig. 4 illustrates the model's capability to precisely predict experimental results, showcasing the accuracy of both the model and training. The schematic representation of the developed model is depicted in Fig. 3.

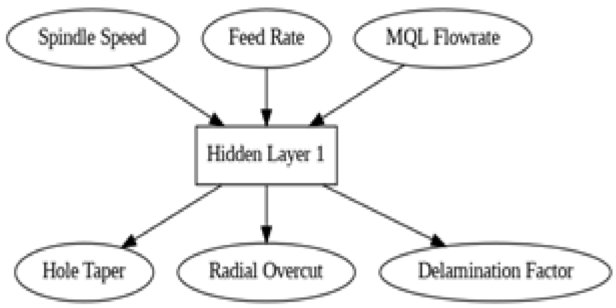


Fig.3. Neural Network

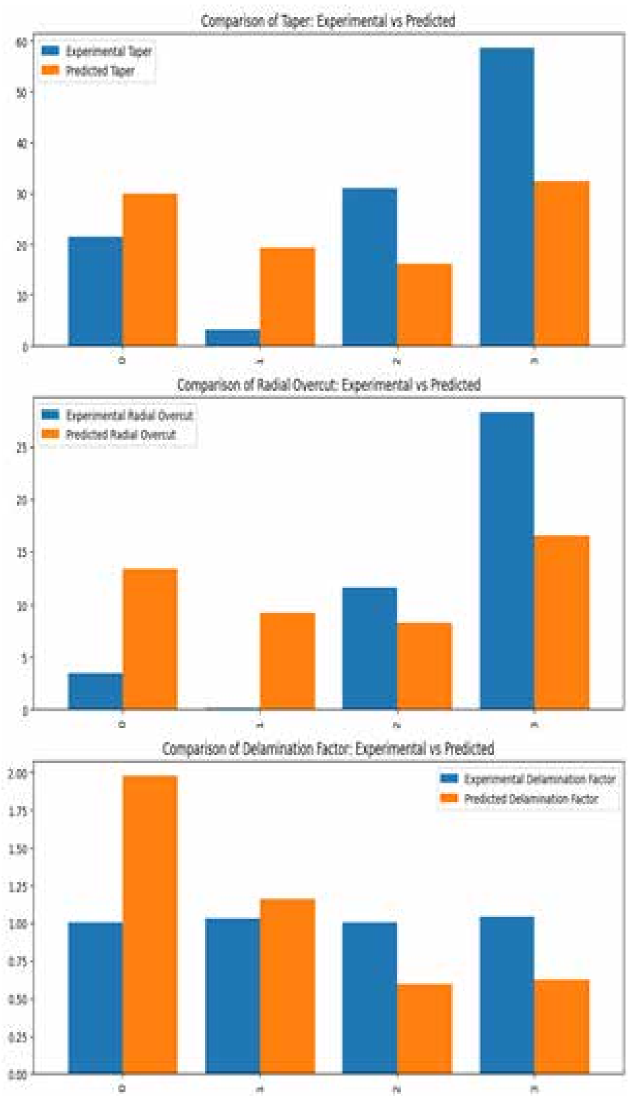


Fig. 4. Contrast between experimental and Artificial Neural Network (ANN) predicted output parameters

Figure 5 depict In ANN modeling, Pearson correlation coefficients reveal the following linear relationships between predicted and experimental values: a moderate positive correlation (0.67) for hole taper, a stronger positive correlation (0.75) for radial overcut, and a weaker positive correlation (0.32) for delamination factor. These coefficients indicate varying degrees of alignment between predictions and experimental outcomes, emphasizing the nuanced predictive capacity of the ANN model for different machining parameters.

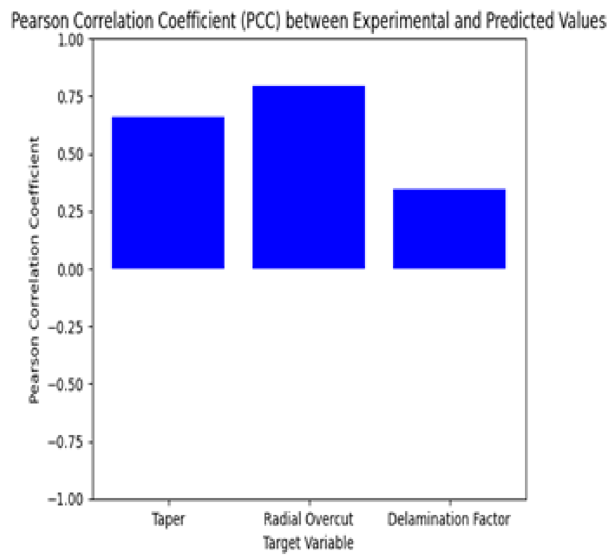


Fig. 5. PCC value of output parameters

RESULT AND DISCUSSION

The study focuses on the mechanical micro-drilling of CFRP-Ti6Al4V stack composites, crucial in aerospace applications. The hybrid nature of these composites addresses the limitations of metal alloys, making them essential in high-performance engines. The mechanical micro-drilling process, employing a peck drilling cycle, is indispensable for applications across various industries. Challenges arise due to poor machinability, leading to delamination and Ti burrs, resulting in severe hole damage and increased machining costs. Inefficiencies in cutting parameters and tool wear compound these issues.

The research, building on the work of Kundiya et al. [13], proposes an artificial neural network (ANN) modeling and optimization approach as a cost-effective alternative to experimental research. The Sequential model with Relu activation function is employed, showcasing effectiveness in capturing nonlinear patterns. The selected network architecture, 3-4-3, demonstrates a low mean absolute prediction error (MAPE) of 7.144, with robust regression coefficients (R) for hole taper (0.9521), radial overcut (0.9824), and delamination factor (0.9236).

Figure 2 illustrates the nonlinear relationship between the number of neurons and MAPE, emphasizing the importance of balancing neural network complexity. Table 2 verifies the model's accuracy, with low MAPE values and strong correlations, showcasing its effectiveness in predicting experimental outcomes. The developed model, depicted in Fig. 3, accurately predicts experimental results, as demonstrated in Fig. 4. Pearson correlation coefficients (PCC) in Fig. 5 reveal varying degrees of alignment for different output parameters. A moderate positive correlation (0.67) is observed for hole taper, a stronger correlation (0.75) for radial overcut, and a weaker correlation (0.32) for delamination factor.

In summary, the ANN model provides a valuable tool for optimizing the mechanical micro-drilling process, offering efficiency and cost-effectiveness compared to traditional experimental research. The study contributes to advancing the understanding of machining parameters, paving the way for enhanced hole quality in micro-drilling applications. The ANN model exhibited superior prediction capabilities compared to the RSM model developed by Kundiya et al. [13] for the identical problem.

CONCLUSION

In conclusion, our study on optimizing mechanical micro-drilling processes for CFRP-Ti6Al4V stack composites employed artificial neural network (ANN) modeling. Significant findings highlighted spindle speed as a crucial factor affecting output parameters. The ANN model, with a 3-4-3 neuron structure, demonstrated superior predictive accuracy (R-squared values: 0.9521, 0.9824, 0.9236) compared to the RSM model. The nonlinear relationship between neuron count and Mean Absolute Percentage Error (MAPE) underscored the importance of model complexity balance. Verification with experimental data confirmed the ANN model's effectiveness, showcasing its potential for advancements in aerospace manufacturing through improved efficiency and machining quality.

REFERENCES

1. Xu J, el Mansori M (2016) Experimental study on drilling mechanisms and strategies of hybrid CFRP/Ti stacks. Compos Struct 157:461–482. https://doi.org/10.1016/j.compstruct. 2016.07.025
2. Isbilir O, Ghassemieh E (2013) Comparative study of tool life and hole quality in drilling of CFRP/titanium stack using coated carbide drill. Mach Sci Technol 17(3):380–409. https://doi. org/10.1080/10910344.2013.806098
3. Shyha I, Soo SL, Aspinwall DK, Bradley S, Dawson S, Pretorius CJ (2010) Drilling of titanium/ CFRP/ aluminium stacks. Key Eng Mater 447(448):624–633. https://doi.org/10.4028/www.sci entific.net/KEM.447-448.624
4. Hasan M, Zhao J, Jiang Z (2017) A review of modern advancements in micro drilling techniques [Online]. Available: https://ro.uow.edu.au/eispapers1/758
5. Heinemann R, Hinduja S, Barrow G, Petuelli G (2006) The performance of small diameter twist drills in deep-hole drilling. J Manuf Sci Eng 128(4):884–892. https://doi.org/10.1115/1. 2335859
6. O, Brinksmeier E (2014) Tool wear analyses in low frequency vibration assisted drilling of CFRP/Ti6Al4V stack material. Procedia CIRP 14:142–147
7. Lin YC, Tsao CC, Hsu CY, Hung SK, Wen DC (2012) Evaluation of the characteristics of the microelectrical discharge machining process using response surface methodology based on the central composite design. Int J Adv Manuf Technol 62(9–12):1013–1021. https://doi.org/10. 1007/s00170-011-3745-0
8. Natarajan U, Periyanan PR, Yang SH (2011) Multiple-response optimization for micro-endmilling process using response surface methodology. Int J Adv Manuf Technol 56(1– 4):177–185. https://doi.org/10.1007/s00170-011-3156-2
9. Landge RR (2017) Analysis of micro-drilling process using response surface methodology [Online]. Available: http://www.ripublication.com
10. SenthilKumar M, Prabukarthi A, Krishnaraj V (2013) Study on tool wear and chip forma-tion during drilling carbon fibre reinforced polymer (CFRP)/titanium alloy (Ti6Al4V) stacks. Procedia Engg 64:582–592 .

11. Prabukarthi A, Senthilkumar M, Krishnaraj V (2016) Study on drilling of CFRP/Ti6Al4V stack with modified twist drills using acoustic emission technique. Steel Compos Struct 21:573–588

12. Shunmugesh K, Panneerselvam K (2018) Multi-performance optimization of micro-drilling using Taguchi technique based on membership function

13. Rahul Kundiya, Raju Pawade, S Yadav, N. Sarode, J. Acharya, "Analysis Of Hole Characteristics In Mechanical Micro Drilling Of Cfrp-Ti6al4v Stack Composite" , LNME, Springer. https://doi.org/10.1007/978-981-99-6601-1_5

14. Jitendra Acharya, Rahul Kundiya, "A Review On Mechanical Micro Drilling Of Cfrp-Ti6al4v Stacked", International Research Journal of Modernization in Engineering Technology and Science, Volume 05/Issue 06/June 2023. ISSN – 2582-5208 https://www.doi.org/10.56726/IRJMETS41334

15. Rahul Kundiya, Shubhangi Chougule, "Optimization of Mechanical Drilling of Metal Matrix Composite using Grey Relational Analysis: A Comparative Study", IJRPR, Volume04/Issue06/2023, ISSN- 2582-8421, https://doi.org/10.55248/gengpi.4.623.44589

16. Pranav Sawant, Rahul Kundiya, "Optimization of Process Parameters in Wire EDM Process of Titanium Alloy", International Research Journal of Modernization in Engineering Technology and Science, Volume 05/Issue 06/June 2023. ISSN – 2582-5208, https://www.doi.org/10.56726/IRJMETS41725

17. Rahul kundiya, Shubham bhagwat, Application of JAYA Algorithm in Opstimization of Mechanical Drillimg of Metal Matrix Compsosite, International Research Journal of Modernization in Engineering Technology and Science, Volume 04/Issue 06/June 2022. ISSN – 2582-5208, pp-133-140

18. Djavanroodi F., Omranpour B., Sedighi M. Artificial neural network modeling of ECAP process, Materials and Manufacturing Processes, 2013, 28, 276–281.

19. Fausett L V. Fundamentals of Neural Networks: Architectures,Algorithms and Application, Prentice – Hall, New York, 1994.

20. Kuldip Singh Sangwana, Sachin Saxenaa, Girish Kanta, "Optimization of Machining Parameters to Minimize Surface Roughness using Integrated ANN-GA Approach", Procedia CIRP 29 (2015) 305 – 310, Sciencedirect. doi: 10.1016/j.procir.2015.02.002

21. Elizabeth Champa-Bujaico, Ana M. Díez-Pascual , Alba Lomas Redondo, Pilar Garcia-Diaz, "Optimization of mechanical properties of multiscale hybrid polymer nanocomposites: A combination of experimental and machine learning techniques", Composites Part B 269 (2023) 111099, https://doi.org/10.1016/j.compositesb.2023.111099

22. J. F. Fatriansyah et.al., "Prediction and optimization of mechanical properties of Ni based and FeeNi based super alloys via neural network approach with alloying composition parameter", JMR&T, Scincedirect (2023). https://doi.org/10.1016/j.jmrt.2023.04.065

Design and Comparative Analysis of Magnesium-Zinc-Calcium Base Alloy Wheel using Artificial Neural Network

Nutan Diwan
✉ nutandiwan1802@gmail.com

Govind Sahu
✉ sahug27@gmail.com

Bhavyavesh Sahu
✉ bhavyaveshsahu@gmail.com

Department of Mechanical Engineering
Government Engineering College
Raipur, Chhattisgarh

ABSTRACT

The study focuses on the design and comparative analysis of alloy wheels using Magnesium-Zinc-Calcium base alloy. Magnesium alloys are gaining attention in various industries due to its lower density, higher specific strength, good damping capacity, and excellent castability compared to traditional Al alloy. In this work, MATLAB's neural network tool were used to predict the properties of Magnesium-Zinc-Calcium base. The neural network model was trained using a MATLAB dataset that included various mechanical characteristics such as ultimate tensile strength, thermal conductivity, yield strength, elongation, density and Young's modulus. The study also compared the properties of the Magnesium-Zinc-Calcium base alloy with aluminium alloy which is commonly used for alloy wheels. The factors selected for comparison are strengths and density. The result shows that the Magnesium-Zinc-Calcium base alloy exhibited superior mechanical properties compared to the aluminium alloy which offer lower production cost. The Authors suggest valuable insights for designers and manufacturers for enhancing the performance of alloy wheels. The ANN tool can be used to predict the properties of new materials which serve the reduction of cost and time associated with material development. The study opens new avenues for further research on the use of Magnesium-Zinc-Calcium base alloys in high-performance applications.

KEYWORDS : *Alloy wheel, Magnesium-Zinc-Calcium base alloy, MATLAB simulation, Artificial neural network, Finite element analysis.*

INTRODUCTION

Alloy wheels have become increasingly popular in modern vehicles due to their superior handling [1], fuel efficiency, and aesthetic appeal over traditional steel wheels. Aluminium and magnesium are two common materials used in the manufacturing of alloy wheels due to their lightweight and strong properties. Magnesium is especially beneficial due to its 30% lighter weight and impact-resistant nature [2]. However, its use is mostly limited to racing due to its weathering resistance and design limitations [1]. Recent studies have focused on the use of Magnesium-Zinc-Calcium base alloy in alloy wheel design due to its promising mechanical properties. This alloy exhibits excellent strength-to-weight ratios, making it an ideal choice for lightweight applications such as alloy wheels. Moreover, it has better castability than other magnesium alloys, making it easier to manufacture complex shapes with fewer defects. A neural network can be described as a collection of individual processing units, or neurons, that are linked together within a network using weighted connections [3, 4]. In this study MATLAB's neural network tool were adopted to predict the properties of Magnesium-Zinc-Calcium base alloy. The factors such as ultimate tensile strength, thermal conductivity, yield strength, elongation, density and Young's modulus were selected to train the ANN tool.

PROBLEM IDENTIFICATION

The use of traditional aluminium alloys in the manufacturing of alloy wheels have various restrictions, such as poor rigidity and strength which can negatively impact the performance of alloy wheels. Furthermore, aluminium alloys have a high density, which limits their potential for lightweight applications. These limitations have prompted the search for alternative materials that can enhance the performance of alloy wheels. Magnesium-based alloys have emerged as promising alternatives to traditional aluminium alloys, as they exhibit superior mechanical properties, such as lower density, good damping capacity, and high specific strength. However, magnesium alloys also have some limitations, such as low wear resistance and weak corrosion resistance.

Hence to overcome the mentioned issues it is required to investigate a new material with optimized mechanical properties that can be used in the production of alloy wheels, considering factors such as strength, stiffness, density, corrosion resistance, wear resistance, and cost-effectiveness. The MATLAB's neural network features can be used to predict the properties of Magnesium-Zinc-Calcium base alloy for their applicability.

METHODOLOGY

The study involved collecting data from several research papers on magnesium-based alloys. The data collected included numerous mechanical and physical characteristics, including Young's modulus, elongation, density, and ultimate tensile strength. This data was used to understand the behaviour of magnesium alloys and establish a benchmark for comparison with the new Magnesium-Zinc-Calcium base alloy. Approximately 150 different compositions of Magnesium-Zinc-Calcium base alloys were collected along with their corresponding properties. These compositions were collected from various sources, including research papers and industrial databases. The data collected was tabulated and analysed to identify trends and patterns in the properties of Magnesium-Zinc-Calcium base alloys are shown in table 1.

Table 1. Input Data for MATLAB Neural Network

S. No	Composition	Yield Strength (MPa)	Ultimate Tensile Strength (MPa)	Elongation (%)	Reference
1	MZC	241.709	317.793	15.75	[5]
2	MZC0.3Mn	210.879	272.291	14.14	[5]
3	MZC0.5Mn	302.348	327.572	13.92	[5]
4	MZC0.7Mn	275.226	314.324	15.736	[5]
5	MZC0.9Mn	245.767	312.217	14.676	[5]
6	Mg-5Zn-3.5Sn-0.5Cu-1Mn-0.5Ca	150	200	8	[6]
7	Mg-5Zn-0.5Ca-3.5Sn-1Mn	170	250	10	[6]
8	Mg-5Zn-3.5Sn-1Mn-0.5Cu	170	290	7	[6]
9	Mg-5Zn-3.5Sn-1Mn	165	240	13	[6]
10	Mg-0.2Ca-4Zn	58	255	17.5	[7]
11	Mg-0.16Mn-4Zn-0.5Ca	175	180	0.2	[7]
12	Mg-0.5Ca-1.2Zn	60	120	3.2	[7]
13	Mg-1Zn-1Ca	45	125	5.7	[7]
14	Mg-2Zn-1Ca	92	143	7.3	[7]
15	Mg-3Zn-1Ca	57	160	8.3	[7]
16	Mg-4Zn-1Ca	63	182	9.1	[7]
17	Mg-5Zn-1Ca	65	173	8.2	[7]
18	Mg-6Zn-1Ca	67	145	4.5	[7]
19	AX51	128	192	7	[8]
20	AX52	161	228	13	[8]

21	AXJ	190	238	8	[8]
22	ZAX8506	146	219	5	[8]
23	AJ52x	145	202	4	[8]
24	AJ51x	145	202	4	[8]
25	AZ91D	157	239	4.7	[8]
26	AS41	132	249	8.9	[8]
27	ZAX8502	165	230	3	[8]
28	ZAX8512	151	206	3	[8]
29	Mg-2Sn-1.95Ca-0.5Mn	450	462	5	[9]
30	Mg-2Sn-2Ca	358	365	8.9	[9]
31	Mg-0.17Mn-8.32Sn-1.85Zn	256	324	13.5	[9]
32	Mg-5Al-3.5Ca-1Mn	322	361	16	[9]
33	Mg-8Al-0.3Mn-1Zn-1Ca	275	371	17.1	[9]
34	Mg-1.5Ca-9Al-2.5Sn	230	309	7.5	[9]
35	Mg-7Sn-4Al-1Zn	221	340	15.1	[9]
36	Mg-1Sn-0.5Zn-0.5Ca	104	331	30.5	[9]
37	Mg-1Sn-0.5Zn-2Ca	180	300	17.9	[9]
38	Mg-0.5Cu-8Sn-2Zn	365	388	5.8	[9]
39	Mg-0.44Mn-1.1Al-0.33Ca	272	295	11.2	[9]
40	Mg-0.5Al-1Mn	248	263	33.4	[10]
41	Mg-7Al-5Zn	218	345	24	[10]
42	Mg-1.2Al-1.6Zn-0.5Ca-0.4Mn	210	282	30.1	[10]
43	Mg-0.21Mn-0.17Ag-8.8Al-0.47Zn	131	344	34	[10]
44	Mg-8Gd-3Y-0.4Zr	650	710	4.5	[10]
45	Mg-1.6Zn-1.2Al-0.5Ca-0.4Mn	210	282	30.1	[10]
46	Mg-1Gd-0.5Mn	146	211	33	[10]
47	Mg-1.5Mn-0.4Al	170	213	52.5	[10]
48	Mg-6Al-1Ca	125	260	27	[11]
49	Mg-2Y-2Zn	145	256	5.7	[11]
50	Mg-6Gd-3Y-0.5Zr	251	340	6.2	[11]
51	Mg-1.74Gd-0.5Y-1.8Zn-0.4Zr	99	175	15.8	[11]
52	Mg-4Al-2Gd-3La-0.3Mn	181	284	14	[11]
53	Mg-4Zn-1La	108	199	8.2	[11]
54	Mg-1Zn-1Mn-8Gd-4Y	214	268	1.8	[11]
55	Mg-0.2Ca-1Zn-0.1Mn	68	182	9.2	[9]
56	Mg-1Ca	377	392	2	
57	AT72 (Mg-7Al-2Sn)	158	251	6.3	[12]
58	AT96(Mg-9Al-6Sn)	189	216	1.8	[12]
59	AZEX4441(Mg-4Al-4Zn-4Re-1Ca)	185	233	4.2	[12]
60	WZA631(Mg-6Y-3Zn-1Al)	175	285	9.8	[12]

61	Mg-4Al-3La-2Sm-0.3Mn	170	266	11.2	[12]
62	AM50A	109.1	208.2	9.6	[10]
63	AZ31	185	263	23	[12]
64	AZ91	160	150	2.511	[12]
65	WE43	170	220	17	[12]
66	MG-10Zn-5Al	188	235	5.6	[12]
67	Mg-3.5Sm-0.4Zr-2Yb-0.6Zn	198	266	4.9	[9]
68	Mg-8.1Gd-4Y-1Zn	303	373	11	[9]
69	Mg-9.2Gd-0.9Mn-3.3Y-1.2Zn	345	418	6.8	[9]
70	Mg-8Gd-3Yb-1.2Zn-0.5Zr	413	425	5.5	[9]
71	Mg-8.3Gd-1.1Mn-4.2Y-1.4Zn	282	388	16.4	[9]
72	Mg-8.8Gd-3.4Y-1Zn-0.8Mn	362	415	8.3	[9]
73	Mg-0.4Zr-15Gd-1Zn	465	524	4	[9]
74	Mg-0.5Mn-1.3Y-0.9Zn-12.6Gd	543	564	1.2	[9]
75	Mg-0.6Zr-9.5Gd-3.8Y	227	334	7.3	[9]
76	Mg-1.0Zn-0.4Zr-8.2Gd-3.8Y	393	447	16	[9]
77	Mg-0.2Ca-3.6Zn-0.6Y	317	357	6.4	[9]
78	Mg-8Al-0.3Mn-1Zn-1Ca	275	371	17.1	[9]
79	Mg–0.17Mn–8.32Sn–1.85Zn	256	324	13.5	[9]
80	Mg-0.5Mn-2.0Sn-1.95Ca	450	462	5	[9]
81	Mg-0.8Zr-5.5Zn-4Sm	227	293	28.1	[9]
82	Mg–0.17Nd–1.2Zn–0.35Zr	169	231	23	[9]
83	Mg-0.6Zn-0.4Sn-0.7Y	188	252	33.1	[9]
84	Mg-0.5Ca-1.0Sn-0.5Zn	104	331	30.5	[9]
85	Mg-2.0Ca-1.0Sn-0.5Zn	180	300	17.9	[9]
86	Mg-5Y-1Al	150	316	17	[9]
87	Mg–7Al–5Zn	218	345	24	[9]
88	Mg-3Zn-2Gd-0.5Zr	285	314	24	[9]
89	Mg-0.5Mn-2Gd	189	243	50	[9]
90	Mg–0.5Al–1Mn	248	263	33.4	[9]
91	Mg-0.5Zr-2.1Nd-0.2Zn	220	267	48.8	[9]
92	Mg-4Al-2La	221	302	21.1	[9]
93	Mg-4Al-4La	242	311	15	[9]
94	Mg-4Al-6La	256	337	8.4	[9]
95	Mg-4Zn-0.5Ca	355.3	385.7	10.2	[13]
96	M g-4.5Al-1Zn	120	150	3	[14]
97	Mg-2Z-1Al-0.3Ca	205	230	10	[14]
98	Mg-6Zn-1Mn	170	284	17.1	[14]
99	ZWK611	114.9	201.83	5.4	[15]
100	ZWK611+.3Ca	116.1	206.38	4.8	[15]

101	ZWK611+.5Ca	120.51	198.77	6.24	[15]
102	ZWK611+.7Ca	125.48	190.47	5.14	[15]
103	ZXM300	57	145	7	[14]
104	ZXM320	58	76	0.9	[14]
105	ZX500	83	156	3.7	[14]
106	ZX510	67	69	0.3	[14]
107	Mg-6Gd-3Y-.4Zr	198	331	7.8	[14]
108	Mg-8Gd-3Y-.4Zr	222	362	7.6	[14]
109	Mg-0.4Zr-10Gd-2Y	239	362	4.7	[8]
110	Mg-0.4Zr-10Gd-3Y	241	370	4.1	[8]
111	Mg-12Gd-3Y-.4Zr	246	328	1.1	[8]
112	Mg-10.4Gd-3.3Y-.46Zr	237	348	3	[8]
113	Mg-10Gd-1Y-1Zr	135	215	12	[8]
114	Mg-10Gd-3Y-1Zr	152	235	6.5	[8]
115	Mg-10Gd-5Y-1Zr	285	300	1	[8]
116	Mg-10Gd-3.74Y-.25Zr	268	325	5.1	[8]
117	Mg-10Gd-3.3Y-.41Zr	264	383	1.5	[8]
118	Mg-6Gd-3Y-.5Zr	173	248	17.5	[8]
119	Mg-.8Al-10Gd-3Y	227	353	3.5	[8]
120	Mg-6Gd-2Sm-1Zr	108	230	19.8	[8]
121	Mg-8Gd-2Sm-1Zr	195	329	7.7	[8]
122	Mg-10Gd-2Sm-1Zr	237	347	3.2	[8]
123	Mg-6Gd-2Nd-1Zr	182	342	7.9	[8]
124	Mg-8Gd-2Nd-1Zr	200	342	5	[8]
125	Mg-11Gd-2Nd-1Zr	224	353	3.7	[8]
126	Mg-10Gd-0.4Zr-3Y-1.2Zn	230	330	3	[8]
127	Mg-1.0Zn-0.4Zr-10Gd-3Y	253	364	2	[8]
128	Mg-0.6Zr-17.4Gd-1.1Zn	278	405	2.5	[8]
129	Mg-1.8Zn-0.5Zr-14Gd-3Y	230	366	2.8	[8]
130	Mg-1.8Zn-6.5Gd-2.5Dy	295	392	6.1	[8]
131	Mg-2.5Gd-1.0Zn-0.16Zr	260	366	3.3	[8]
132	Mg-14Gd-2Zn-0.5Zr	292	404	5.3	[8]
133	Mg-0.3Zr-18.2Gd-1.9Ag	293	414	2.2	[8]
134	Mg-1.8Ag-0.4Zr-8.5Gd-2.3Y	268	403	4.9	[8]
135	Mg-.4Zr-15.6Gd-1.8Ag	328	423	2.6	[8]
136	Mg-3.5Y-2Nd-1.3Gd-.4Zr	196	345	7	[8]
137	Mg-4Y-4Sm-.5Zr	217	348	6.9	[8]
138	Mg-10Y-2.5Sm	200	216	3.5	[8]
139	Mg-.9Gd-.4Zr-3.4Y-1.9Nd	202	312	6.2	[8]
140	Mg-3Y-2.5Nd-1Gd-.5Zn-.5Zr	186	324	9.7	[8]

141	Mg-1.2Gd-.2Zn-.5Zr-4.3Y-3Nd	214	316	4.4	[8]
142	Mg-.2Zn-.4Zr-4Y-2.4Nd	265	330	6.5	[8]
143	Mg-11Y-5Gd-2Zn-.5Zr	240	307	1.4	[8]
144	Mg-2Gd-0.6Zr	150	207	36.8	[13]
145	Mg-4Gd-.6Zr	145	206	43.4	[13]
146	Mg-6Gd-0.6Zr	168	237	33.4	[13]
147	Mg-3.25Ni-6.25Y	460	526	8	[13]
148	AZ31B	220	288	8	[5]
149	LA141A	123	144	23	[5]

Note:- Input data of Thermal conductivity, Density and Young's Modulus are taken from the following review paper[5-23].

To predict the properties of the new Magnesium-Zinc-Calcium base alloy, a MATLAB neural network (NN) tool was used. The tool was trained using the collected data set and the properties of Magnesium-Zinc-Calcium base alloys as shown in Fig.1.

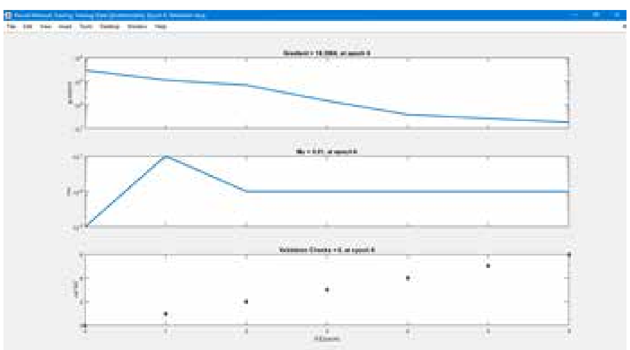


Fig. 1 Neural Network training state

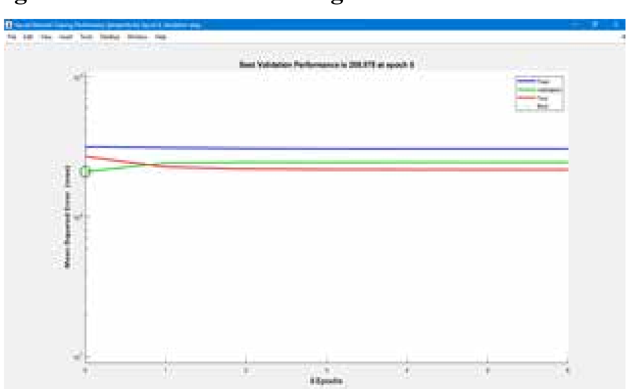


Fig. 2 Neural Network Training Performance

The NN tool was used to predict the mechanical and physical properties of the new Magnesium-Zinc-Calcium base alloy based on its composition. The tool used the input data to identify correlations and trends between the properties and the alloy's composition. The output of the NN tool was a prediction of the alloy's properties based on its composition as shown Fig.2 and Fig.3.

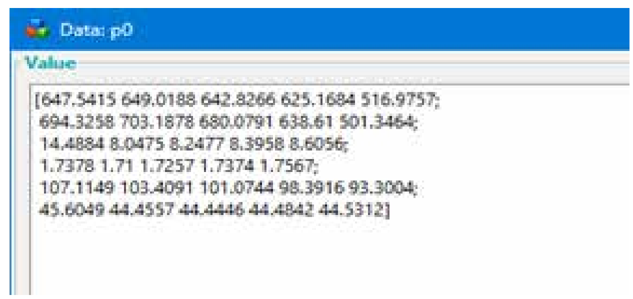


Fig. 3 Result of MATLAB for Different Composition

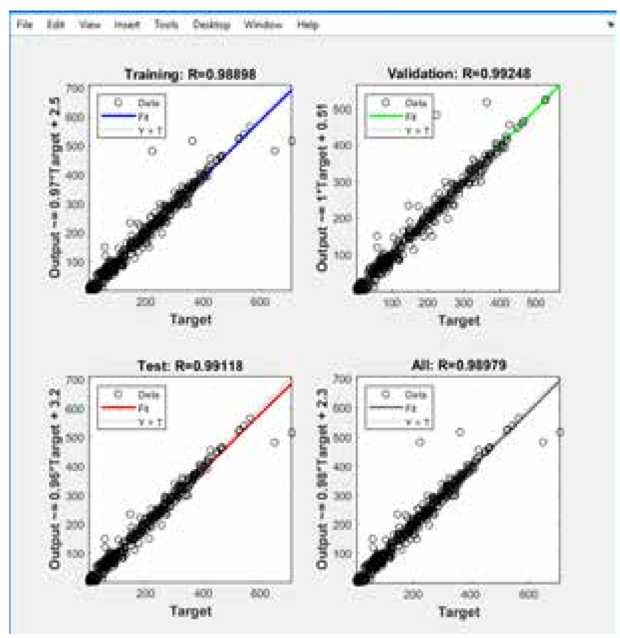


Fig. 4 Neural Network Training Regression

Overall, the combination of data collection, analysis, and NN tool prediction provided valuable insights into the potential performance of the new Magnesium-Zinc-Calcium base alloy.

Composition Table (New Alloy)

In order to determine the optimal percentage of certain elements, we relied on previous research works. For other elements, we utilized a hit and trial method to arrive at the optimal composition. By combining these two approaches, we were able to determine the ideal ratios for all the necessary components.

Table 2.

S. No	Mg	Al	Zn	Ca	Si	Mn	Ag	Sn	Fe	CU	Ni
1	86.83	5.5	3	0.2	0.06	0.5	0.001	3.5	0.003	0.4	0.006

Property Table (New Alloy)

Table 3

Composition	Mg5.5 Al3Zn. 2Ca.06 Si.5 Mn.001 Ag 3.5 Sn.003 Fe.4 Cu.006 Ni
Yield Strength	649.01 (MPa)
Ultimate Tensile Strength	703.18 (MPa)
Elongation	8.04 (%)
Thermal Conductivity	103.4 (W/mK)
Density	1.71 (g/cm3)
Young`s Modulus	44.45(GPa)

Structural Analysis of Alloy Wheel

The supplied model is broken down into 63222 elements and 106068 nodes in ANSYS Workbench. Tetrahedron components are employed in a meshing. Meshing is necessary for the model to produce results at any moment. If there are more elements, it will take longer to solve the problem.

Boundary Conditions [24][25]

2000 kg of the vehicle's entire weight is dispersed over its four wheels on a rim.

Every wheel bearing the weight = Total mass /4 =500kg.

Total force applied to each wheel = 500*9.81= 4905N.

The maximum pressure allowed in the car rim =40psi= 40*.00689=.275MPa

The maximum speed of car =160km =216.6 rad /s

Equivalence von mises stress

Maximum equivalent stress of 36.38 MPa was induced at the rim's exterior circumference under the specified boundary conditions. 649.01 MPa is the yield stress for the. In comparison to the material's yield stress, the produced stress is extremely low. The specified load condition can be handled by the model.

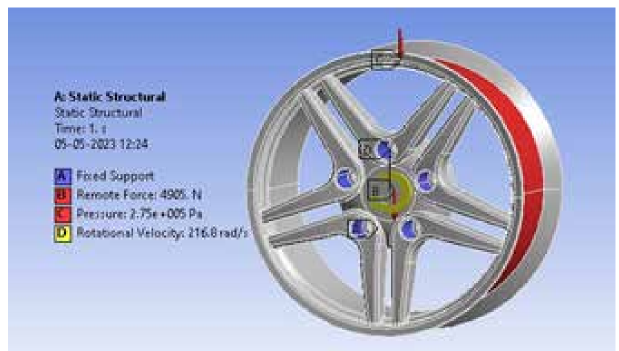


Fig. 5- Boundary Condition for Structural Analysis

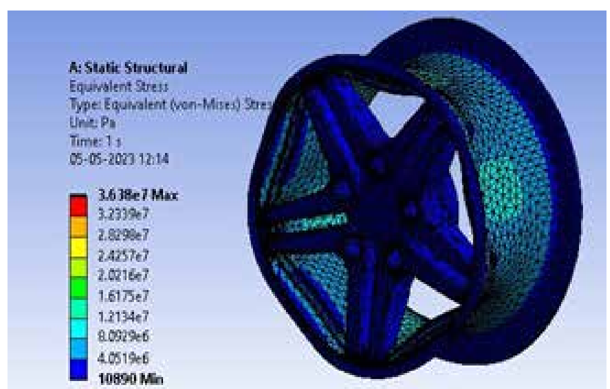


Fig. 6- Max Equivalent Stress of 36.38Mpa is observed

Maximum Principal Stress

The largest primary stress that could be created under the specified boundary conditions was 7.017 MPa at the rim's outside circumference. 649.01 MPa is the yield stress. In comparison to the material's yield stress, the produced stress is extremely low. The specified load condition can be handled by the model.

Total Deformation

The greatest deformation that can be caused at a rim's outside circumference is 0.055148mm in size. The actual percentage of elongation is 8.04%, which is significantly higher than the induced proportion. Therefore, even with the rim's caused deformation, the model will be secure.

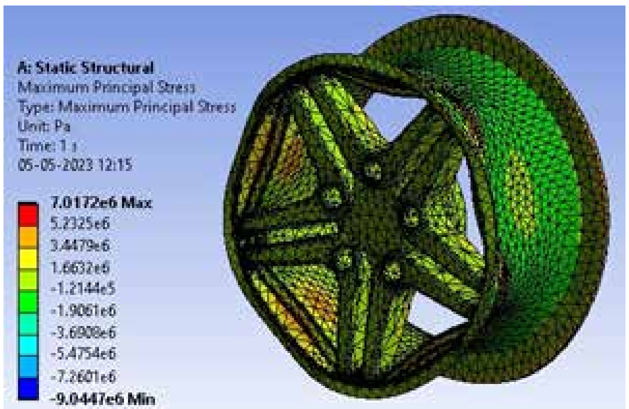


Fig. 7 Maximum Principal Stress of 7.017Mpa is Observed

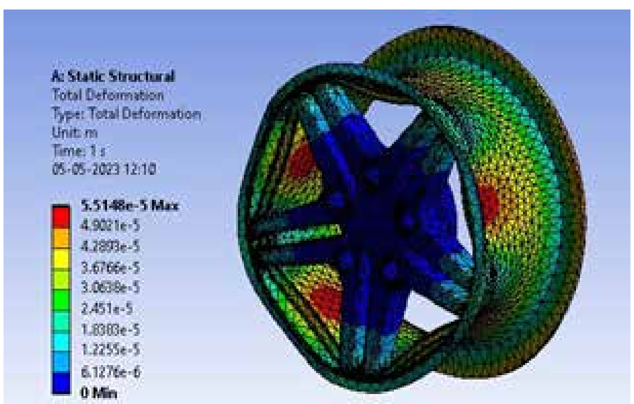


Fig. 8 Total Deformation of 0.055148mm is Observed

Equivalent elastic strain

For the specified loading situation, 81.862X10-5 equivalent elastic strain is induced in the provided model.

Shear stress:

Maximum Shear stress of 18.84 MPa was induced at the rim's exterior circumference under the specified boundary conditions.

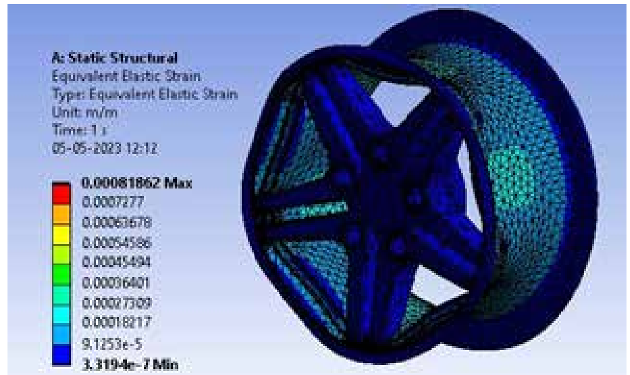


Fig. 9 Elastic Strain of 81.862X10-5 is Observed

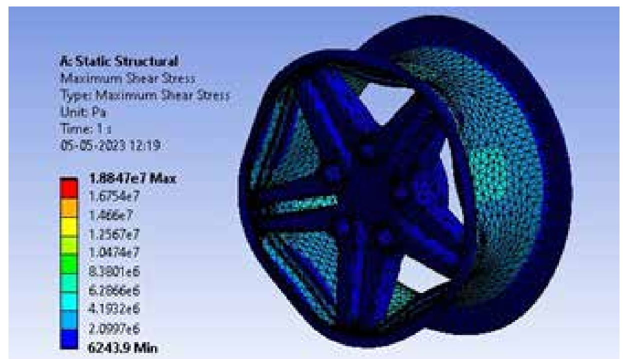


Fig.10 Max Shear Stress of 18.84Mpa is Observed

CONCLUSION

The study comprises the design and comparative analysis of alloy wheels using a magnesium-zinc-calcium base alloy to investigate the potential of a new material for mitigating the limitations of traditional alloys for enhanced performance of alloy wheels. The data required for training the NN model and predicting the properties of the new magnesium-zinc-calcium base alloy were gathered from various research papers for available alloys.

The result revealed that the magnesium-zinc-calcium base alloy has the potential to provide better mechanical properties, such as greater strength and stiffness, than conventional aluminium alloys. The authors suggest that a new alloy could be a suitable replacement material for alloy wheels.

The study also highlighted the importance of advanced analytical tools and techniques, such as MATLAB's neural network tool, for predicting the properties of new materials without physical testing. This approach can save time and resources and provide a preliminary assessment of the potential performance of new materials.

The result of finite element analysis on alloy wheels prepared with a new magnesium-zinc-calcium base alloy shows that the wheels are safe to use under the given conditions. The induced stress is significantly lower than the yield strength, indicating that the wheels are capable of withstanding the anticipated load without compromising their structural integrity. The outcome also reveals the effectiveness of the new alloy, which has improved mechanical properties and could have a significant impact on the design and manufacture of high-performance wheels in various industries. The use of magnesium zinc-calcium base alloy in the production of alloy wheels could lead to improved performance, reduced weight, and increased fuel efficiency.

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REFERENCE

1. A. Naim, R. Kumar, and S. Bhatia, "A review paper on materials used for manufacturing of alloy wheels," IOP Conf. Ser. Mater. Sci. Eng., vol. 1136, no. 1, p. 012006, 2021.
2. S. F. S. Musheer and D. V. V. Mane, "Design and Analysis of Alloy Wheel Rim by Using Different Material," Int. J. Res. Appl. Sci. Eng. Technol., vol. 10, no. 8, pp. 50–59, 2022.
3. D. P. B. T. B. Strik, A. M. Domnanovich, L. Zani, R. Braun, and P. Holubar, "Prediction of trace compounds in biogas from anaerobic digestion using the MATLAB Neural Network Toolbox," Environ. Model. Softw., vol. 20, no. 6, pp. 803–810, 2005.
4. M. H. Al-Shamisi, A. H. Assi, and H. A. N. Hejase, "Artificial neural networks for predicting global solar radiation in Al Ain City - UAE," Int. J. Green Energy, vol. 10, no. 5, pp. 443–456, 2013.
5. Y. Y. Han, C. You, Y. Zhao, M. F. Chen, and L. Wang, "Effect of Mn Element Addition on the Microstructure, Mechanical Properties, and Corrosion Properties of Mg-3Zn-0.2Ca Alloy," Front. Mater., vol. 6, no. December, pp. 1–10, 2019.
6. S. Agarwal, J. Curtin, B. Duffy, and S. Jaiswal, "Biodegradable magnesium alloys for orthopaedic applications: A review on corrosion, biocompatibility and surface modifications," Mater. Sci. Eng. C, vol. 68, pp. 948–963, 2016.
7. B. Istrate, C. Munteanu, and I. Antoniac, "Current Research Studies of Mg – Ca – Zn Biodegradable Alloys Used as Orthopedic Implants — Review," pp. 1–18, 2024.
8. G. Wu, C. Wang, M. Sun, and W. Ding, "Recent developments and applications on high-performance cast magnesium rare-earth alloys," J. Magnes. Alloy., vol. 9, no. 1, pp. 1–20, 2021.
9. J. Song, J. She, D. Chen, and F. Pan, "Latest research advances on magnesium and magnesium alloys worldwide," J. Magnes. Alloy., vol. 8, no. 1, pp. 1–41, 2020.
10. A. Javaid and F. Czerwinski, "Progress in twin roll casting of magnesium alloys: A review," J. Magnes. Alloy., vol. 9, no. 2, pp. 362–391, 2021.
11. K. B. Nie, X. J. Wang, K. K. Deng, X. S. Hu, and K. Wu, "Magnesium matrix composite reinforced by nanoparticles – A review," J. Magnes. Alloy., vol. 9, no. 1, pp. 57–77, 2021.
12. G. G. Wang and J. P. Weiler, "Recent developments in high-pressure die-cast magnesium alloys for automotive and future applications," J. Magnes. Alloy., vol. 11, no. 1, pp. 78–87, 2023.
13. T. Itoi, K. Takahashi, H. Moriyama, and M. Hirohashi, "A high-strength Mg-Ni-Y alloy sheet with a long-period ordered phase prepared by hot-rolling," Scr. Mater., vol. 59, no. 10, pp. 1155–1158, 2008.
14. A. Gungor and A. Incesu, "Effects of alloying elements and thermomechanical process on the mechanical and corrosion properties of biodegradable Mg alloys," J. Magnes. Alloy., vol. 9, no. 1, pp. 241–253, 2021.
15. Y. G. Jung et al., "Effect of Ca addition on the microstructure and mechanical properties of heat-treated Mg-6.0Zn-1.2Y-0.7Zr alloy," J. Magnes. Alloy., vol. 9, no. 5, pp. 1619–1631, 2021.
16. C. Wang, T. Luo, Y. Liu, T. Lin, and Y. Yang, "Microstructure and mechanical properties of Mg-5Zn-3.5Sn-1Mn-0.5Ca-0.5Cu alloy," Mater. Charact., vol. 147, no. September 2018, pp. 406–413, 2019.
17. M. Golrang, M. Mobasheri, H. Mirzadeh, and M. Emamy, "Effect of Zn addition on the microstructure and

mechanical properties of Mg-0.5Ca-0.5RE magnesium alloy," J. Alloys Compd., vol. 815, p. 152380, 2020.

18. J. Wang et al., "Effect of trace Ni addition on microstructure, mechanical and corrosion properties of the extruded Mg–Gd–Y–Zr–Ni alloys for dissoluble fracturing tools," J. Magnes. Alloy., vol. 9, no. 5, pp. 1632–1643, 2021.

19. W. Mo, L. Zhang, G. Wu, Y. Zhang, W. Liu, and C. Wang, "Effects of processing parameters on microstructure and mechanical properties of squeeze-cast Mg-12Zn-4Al-0.5Ca alloy," Mater. Des., vol. 63, pp. 729–737, 2014.

20. P. Yin, N. F. Li, T. Lei, L. Liu, and C. Ouyang, "Effects of Ca on microstructure, mechanical and corrosion properties and biocompatibility of Mg-Zn-Ca alloys," J. Mater. Sci. Mater. Med., vol. 24, no. 6, pp. 1365–1373, 2013.

21. K. Singh, G. Singh, and H. Singh, "Review on friction stir welding of magnesium alloys," J. Magnes. Alloy., vol. 6, no. 4, pp. 399–416, 2018, doi: 10.1016/j.jma.2018.06.001.

22. D. S. Kumar, C. T. Sasanka, K. Ravindra, and K. N. S. Suman, "Magnesium and Its Alloys in Automotive Applications – A Review," Am. J. Mater. Sci. Technol., vol. 4, no. 1, pp. 12–30, 2015.

23. H. R. Bakhsheshi-Rad, M. R. Abdul-Kadir, M. H. Idris, and S. Farahany, "Relationship between the corrosion behavior and the thermal characteristics and microstructure of Mg-0.5Ca-xZn alloys," Corros. Sci., vol. 64, pp. 184–197, 2012.

24. M. Dabair, "Static Structural, Modal and Harmonic Analysis of Alloy Car Wheel Rim using ANSYS Workbench," Int. J. Eng. Res. Technol., vol. 8, no. 07, pp. 599–611, 2019.

25. V. I. S. Ekhar and A. C. H. M. Ouli, "Design and Performance Analysis of Alloy Wheels using CATIA ANSYS Modeling Tool," Int. J. Sci. Eng. Technol. Res., vol. 03, no. 43, pp. 8789–8793, 2014.

Engineering Insights into NiTinol Shape Memory Alloy Evolution

Rahul Kundiya, Mukundrao Kadam
Department of Mechanical Engineering
BVDU College of Engineering
Pune, Maharashtra
✉ rahul.kundiya@vpmmpcoe.org
✉ makadam@bvucoep.edu.in

Pradeep Jadhav
Principal & Professor
Bharati Vidyapeeth's College of Engg. for Women,
Pune, Maharashtra
✉ pradeep.jadhav@bharatividyapeeth.edu

Pranav Sawant
Department of Mechanical Engineering
VPM's Maharshi Parshuram College of Engineering
Velneshwar, Maharashtra

ABSTRACT

This review paper provides a comprehensive overview of NiTinol, a prominent Shape Memory Alloy composed of nickel and titanium. NiTinol exhibits remarkable characteristics, including the shape memory effect and superelasticity, making it a unique and highly versatile material in various industries. The shape memory effect (SME) is a key feature of NiTinol, driven by a diffusionless solid phase transformation. It allows NiTinol to return to its original shape when heated, enabling its application in automotive, aerospace, biomedical, communication, and many other domains. Superelasticity, often referred to as the "pseudoelastic effect," further enhances its utility by enabling NiTinol to undergo substantial deformations and recover its shape. The paper delves into the manufacturing of NiTinol, highlighting the significance of adhering to strict standards, particularly in medical applications. Various manufacturing methods, including casting and powder metallurgy processes, are discussed, along with their advantages and limitations. Looking to the future, the application range of NiTinol is expected to expand, driven by increased profitability and demand. To address the challenges of high-speed machining and tool wear, further research is essential. Innovative solutions, such as textured cutting tools and additive manufacturing, hold promise in advancing NiTinol's applications.

KEYWORDS *: NiTinol, Shape memory alloy, Manufacturing, Applications, Superelasticity.*

INTRODUCTION

Because of its ability to produce maximum recovery strain under mechanical tension (pseudoelasticity), shape return upon heating (shape memory effect), and excellent biologiccompatibility, shape memory alloys (SMAs) are among the finest actuators for biomedical applications. Shape memory alloys (SMAs) have excellent mechanical characteristics and a high actuation stress, which make them superior to other polymers with shape memory and shape memory hybrids [1]. SMAs have been used in a range of industries, including automotive [2-3], aviation [4-5], biomedical [6, 7], telecommunications [8, 9], composites and constructions [10-11]. The SMAs have a variety of alloyed compositions, each of which has unique features. Despite being inexpensive and commercially accessible, copper- and iron-based SMAs have not been employed very frequently because of their instability, impracticability, and subpar thermomechanical performance [13–14]. The majority of SMAs are NiTi-based because they have greater practical fatigue and biocompatibility features [15].

Although the majority of research points to these materials' strong bio-compatibility, there are still concerns about their performance in vivo and their molecular interactions with cells [16]. The most important of them are stress-assisted corrosion [17] and toxic consequences of ion release [18]. But according to reports, the titanium oxide layer that forms on NiTi serves as a barrier to corrosion and chemical reactions as well as restricting the migration of nickel ions [15–19]. The majority of academics agreed that NiTi's in vivo and in vitro biologiccompatibility makes it particularly suitable for biomedical applications [20-21, 23-24]. The ultimate desired result is greatly shaped by the manufacturing procedures. The manufacturing of NiTi requires particular consideration due to its remarkable shape memory features. It is necessary to have a deeper grasp of NiTi's special qualities in order to build the needed NiTi parts.

The primary purpose of this paper is to provide a comprehensive overview of NiTinol as a Shape Memory Alloy (SMA). We aim to delve into the key aspects of NiTinol, exploring its properties, applications, and manufacturing process. By doing so, we intend to offer a holistic understanding of this remarkable material within the broader context of materials science and engineering. We will thoroughly examine NiTinol, starting with its composition and delving into its unique properties, including the shape memory effect and superelasticity. By providing a comprehensive overview, we aim to give readers a well-rounded understanding of NiTinol's fundamental characteristics.

Properties of NiTi Shape memory alloy

It is essential to comprehend how the shape memory phenomenon of SMAs depends on diffusionless solid phase change in order to comprehend their mechanical behavior [22]. For example, at normal working temperatures, NiTi exhibits two phases (martensite and austenite), where austenite is stable at greater temperatures and martensite at lower temperatures because of their distinct crystal structures [22, 27]. Superelasticity, often referred to as the "pseudoelastic effect," is the ability of NiTinol to undergo large deformations and then fully recover its original shape when the external load is removed. [25-26].

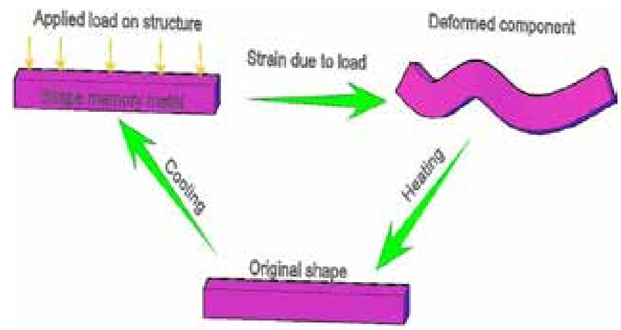

Figure 1. Behavior Pattern of Shape Memory Effect [28]

MANUFACTURING OF NITINOL

Since flaws can be carried over into the finished product, thorough monitoring of every step of manufacturing is essential for the successful healthcare, and automotive use of nitinol [31]. Several standards, including ASTM F2063, limit the maximum oxygen and nitrogen content in medical grade NiTinol to five hundred parts per million (ppm) and the greater dimension of additions in a NiTinol melt meant for the production of medical grade devices to 39 microns [48]. Several nitinol manufacturing processes are covered in this part, with special attention paid to their significance, advantages, disadvantages, and suitability for machining medical-grade nitinol.

Casting/Melting Process

Due to its reactivity and high titanium content, molten nitinol requires processing in a vacuum [29]. Casting processes like VIM, VAR, EBM, and PAM are commonly used for nitinol production, with multiple VAR or VIM followed by VAR being preferred [30,32,33,34,31]. These techniques are briefly discussed in this section, with benefits and drawbacks summarized in Table 1. Additionally, a suitability study based on factors like sensitivity to carbon and oxygen, homogeneity, and chemical composition is conducted to ensure quality, especially for medical-grade applications [34].

Table 1. Benefits and Drawbacks of NiTi Shape Memory Alloy Casting Manufacturing Processes

Method	Strengths	Limitations	References
VIM (Vacuum Induction Melting)	- Because of the tiny batch sizes, operation is simple and flexible. - Cheap and simple to use graphite crucibles. - Good chemical homogeneity in the melt.	- High expenses for processing. - Increased Ni concentration might result from the presence of TiC and carbon particles, which would lower phase transition temperatures. - The potential for segregation and extremely high melt reactivity. - Rapid grain enlargement.	[35, 31, 36, 29, 33]

VAR (Vacuum Arc Remelting)	No requirement for a crucible. - Greater purity than VIM.	- susceptible to having minor inclusions. - Carbon and oxygen pick-up during remelting may be caused by vacuum leakage. - The potential for segregation and extremely high melt reactivity. - Rapid grain enlargement.	[31, 36, 29, 33]
PAM (Plasma Arc Melting)	High plasma flow speed, high energy concentration, and fast heat transfer cause melting to happen quickly.	- Low degassing of molten metal. - Insufficient homogeneity, which necessitates the use of many torches to achieve uniformity.	[30, 36]
EBM (Electron Beam Melting)	- Minimal carbon contamination, with carbon content 4–10 times lower than in VIM.	- Suitable for very small volume production, but less chemical composition control.	[30, 37]

Table 2. Assessment of Nitinol Manufacturing Methods

Method	Choosing the Factors and Their Permissible Ranges Values outside the suggested range are shown in bold.	Suitability Rating
VIM (Vacuum Induction Melting)	- Carbon content: 300-700 ppm (500 ppm is desirable [38]). - Oxygen content: 0.025% (0.05% acceptable) [56] Due to electrodynamic stirring, homogeneity is good [39]. - Included range: 5 to 40 m [40]	Good
VAR (Vacuum Arc Remelting)	- 100 ppm of carbon concentration is less than the required 500 ppm (38, 41) 0.03 weight percent (recommended: 0.05 weight percent) of oxygen [42] - Inclusions: 17 mm (recommended: 39 mm) [43]	Excellent
PAM (Plasma Arc Melting)	- 0.0094 weight percent (recommended: 0.05 weight percent) of carbon - Oxygen level: 0.031 (recommended: 0.05 weight percent). - Poor homogeneity in comparison to VIM - Inclusions of less than 5 m [39]	Good
EBM (Electron Beam Melting)	- 0.012–0.016 weight percent (recommended: 0.05 weight percent) of carbon [44] 0.01 weight percent (recommended: 0.05 weight percent) of oxygen - Poor chemical makeup [44]	Good

Powder metallurgy processes

Both additive manufacturing (AM) and traditional metallurgical methods are part of powder metallurgy (PM) processes [31]. Traditional PM methods involve SHS, HIS, SPS, MIM, and CS, while AM PM methods include LENS, Electron Beam, and SLM [31].

Table 3. Benefits and drawbacks of powder metallurgy nitinol production methods

Method	Strengths	Limitations	References
Conventional Powder Metallurgy Processes CS (Conventional Sintering)	- Low cost - High production rate - Low demand for further processing - Good accuracy - Simple operation - Cheaper than casting procedures - Reduced material waste	- Poor mechanical qualities of the sample - Extended warming periods - Limited pore sizes and shapes (maximum porosity of 40%)	[36, 31, 45]
SHS (Self-Propagating High-Temperature Synthesis)	Low cost - Creates organized, Low energy consumption - Significant porosity (up to 65%)	- Possible formation of secondary phases as a result of incomplete reactions - Poor control of intermetallic phases that causes embrittlement	[46, 31, 47–49]

HIP (Hot Isostatic Pressing)	- Efficient utilization of resources Improved homogeneity, good pore size and shape control, shorter solid-state diffusion time, and production of dense products with isotropic mechanical characteristics Reduced sintering temperature - Fit for big or complicated items	- Pore size and shape restrictions (maximum 40% porosity) - Intermetallic phases (Ti2Ni, Ni3Ti, and Ni4Ti3) are present. - Potentially produced porosities by inert gas - Low rate of production	[50, 31]
SPS (Spark Plasma Sintering)	- Simple operation - Low-temperature high-density sintering rapidly than others conventional powder metallurgy process; High precision control	Costly DC generator is necessary, and it only functions with simple sample shapes.	[51, 31, 52]
MIM (Metal Injection Molding)	- Suitable for items with a near-net form - Extreme geometric accuracy - Economical for big volumes of small-scale, complicated goods. - Up to 98% density achievable	-	[31, 53]
Additive Manufacturing Processes SLS (Selective Laser Sintering)	- Good form control - Good homogeneity and porosity	Costly tooling makes it expensive, and there are also size restrictions on the parts, residual pores, and a lot of impurity phases.	[31, 54]
SLM (Selective Laser Melting)	Can create thick components (97% of cast Nitinol density is conceivable) - Minimized beam distortion - Post-treatment debinding is not necessary	Costly, high energy-demanding, and prone to melt pool instability	[31, 80, 47]
LENS (Laser Engineered Net Shaping)	- Capable of creating components that are very pure, dense, and have excellent microstructures. - Absence of bad periods	-	[31, 55, 56]

FORMING NITINOL

After manufacture, ingots are shaped into tubing, wire, sheet, bar, and ribbon forms through hot working at 600-900 °C, reducing diameters from 500 mm to around 15 cm [35]. Cold working and annealing at 600-800 °C are crucial due to nitinol’s rapid work hardening [58]. Cold-working and aging treatments are necessary for optimal superelastic performance [57].

FUTURE TRENDS AND UTILIZATION

Accordingly, as these materials become more profitable, their application range may expand. This could encourage scientists and business to investigate this substance even further. Similar to this, a need for greater speed machining may arise from an increase in the demand for NiTi goods. In this situation, the facts presented on cutting tool behavior and wear can be useful to cutting tool manufacturers. This material's production calls for careful consideration of its functional qualities. However, only a small number of studies on how machining affects functional parameters including conversion temperatures, conversion enthalpy, and activation energies have been conducted.

One of the main obstacles to high-speed machining of NiTi is tool wear. This restriction is mostly caused by greater temperatures at higher speed levels. Cryogenic cooling and coatings on the surfaces of carbide-cutting tools have previously been claimed to help with this issue at higher cutting speed levels. To improve these materials' machinability rate, more research is needed. Use of textured cutting tools, the application of multilayer coatings, or the use of rotary turning tools are some recommended methodologies for these possible investigations. Other hard-to-cut materials have been successfully machined using these techniques.

When creating items in small numbers and with complicated geometries, additive manufacturing may be a more profitable production method than machining. As a result, AM could be an excellent substitute for some NiTi components. However, AM of NiTi has not yet attracted significant attention. This method' drawbacks, such as poor geometric accuracy and thermomechanical flaws, and the high cost of infrastructure investment may be to blame. However, the AM technique is being used and researched more and more.

CONCLUSION

In conclusion, NiTinol, a nickel-titanium Shape Memory Alloy (SMA), boasts remarkable properties and diverse applications. Its SME and superelasticity make it invaluable in fields like automotive, aerospace, biomedical, and communication. Manufacturing processes, including casting and powder metallurgy, require strict quality control, especially in medical applications. Future advancements may involve higher-speed machining and additive manufacturing, though challenges like tool wear and AM costs remain. Despite obstacles, NiTinol's potential to revolutionize industries is clear, driving ongoing research and innovation.

REFERENCES

1. Zainal MA, Sahlan S, Ali MSM, Micromachined shapememory- alloy microactuators and their application in biomedical devices. Micromachines 6(7):879–901, 2015
2. Stoeckel D, Shape memory actuators for automotive applications. Mater Des 11(6):302–307. https://doi.org/10.1016/0261-3069(90)90013-A, 1990
3. Butera F, Coda A, Vergani G, SpA SG, Shape memory actuators for automotive applications. Nanotec IT newsletter Roma: AIRI/nanotec IT:12–16. https://doi.org/10.1016/0261- 3069(90)90013-A. 2007
4. Bil C, Massey K, Abdullah EJ, Wing morphing control with shape memory alloy actuators. J Intell Mater Syst Struct 24(7):879–898. 2013, https://doi.org/10.1177/1045389X12471866
5. Hartl DJ, Lagoudas DC, Aerospace applications of shape memory alloys. Proc Inst Mech Eng G J aerosp eng 221(4):535–552. 2007, https://doi.org/10.1243/09544100JAERO211
6. Petrini L, Migliavacca F, Biomedical applications of shape memory alloys. 2011. J Metall. https://doi.org/10.1155/2011/501483
7. Kaya A, Kaya I, Karaca HE, Radio frequency U-shape slot antenna design with NiTi shape memory alloys. Microw Opt Technol Lett 55(12):2976–2984. 2013. https://doi.org/10.1002/mop.27977
8. Kaya A, Kaya I, Karaca HE, U-shape slot antenna design with high-strength Ni54Ti46 alloy. Arab J Sci Eng 41(9):3297–3307. 2016. https://doi.org/10.1007/s13369-015-1819-2
9. FuruyaY,Designandmaterialevaluationofshapememory composites. J Intell Mater Syst Struct 7(3):321–330. 1996 https://doi.org/10.1177/1045389X9600700313
10. Kohl M, Shape memory microactuators. Springer Science & Business Media. 2013
11. Kahn H, Huff M, Heuer A, The TiNi shape-memory alloy and its applications for MEMS. J Micromech Microeng 8(3):213 1998. https://doi.org/10.1088/0960-1317/8/3/007
12. Wilkes KE, Liaw PK, The fatigue behavior of shapememory alloys. JOM 52(10):45–51. 2000. https://doi.org/10.1007/ s11837-000-0083-3
13. Huang W, On the selection of shape memory alloys for actuators. Mater Des 23(1):11–19. 2000. https://doi.org/10.1016/S0261-3069(01)00039-5
14. Jani JM, Leary M, Subic A, GibsonMA, A review of shape memory alloy research, applications and

opportunities.Mater Des (1980–2015) 56:1078–1113. 2014. https://doi.org/10.1016/j.matdes.2013.11.084

15. Elahinia MH, Hashemi M, Tabesh M, Bhaduri SB, Manufacturing and processing of NiTi implants: a review. Prog

16. Mater Sci 57(5):911–946. 2012. https://doi.org/10.1016/j.pmatsci.2011.11.001

17. Ryhänen J, Biocompatibility of nitinol. Minim Invasive Ther Allied Technol 9(2):99–105. 2000. https://doi.org/10.3109/13645700009063056

18. Ryhänen J, Niemi E, Serlo W, Niemelä E, Sandvik P, Pernu H, Salo T, Biocompatibility of nickel–titanium shape memory metal and its corrosion behavior in human cell cultures. J Biomed Mater Res 35(4):451–457. 1997.

19. Shih CC, Lin SJ, Chen YL, Su YY, Lai ST, Wu GJ, Kwok CF, Chung KH, The cytotoxicity of corrosion products of nitinol stent wire on cultured smooth muscle cells. J Biomed Mater Res 52(2):395–403. 2000.

20. Bahraminasab M, Sahari BB, NiTi shape memory alloys, promising materials in orthopedic applications. In: Shape memory alloys—processing, characterization and applications. 2013. InTech. https://doi.org/10.5772/48419

21. Shabalovskaya SA, Surface, corrosion and biocompatibility aspects of nitinol as an implantmaterial. BiomedMater Eng 12(1):69–109. 2002

22. Es-Souni M, Es-Souni M, Fischer-Brandies H, Assessing the biocompatibility of NiTi shape memory alloys used for medical applications. Anal Bioanal Chem 381(3):557–567. 2005. https://doi. org/10.1007/s00216-004-2888-3

23. Sun L, Huang WM, Nature of themultistage transformation in shape memory alloys upon heating. Met Sci Heat Treat 51(11): 573–578. 2009. https://doi.org/10.1007/s11041-010-9213-x

24. Stanford MK, Thermophysical properties of 60-nitinol for mechanical component applications, 2012.

25. Stanford MK, Hardness and microstructure of binary and ternary nitinol compounds, 2016.

26. Lagoudas DC, Shape memory alloys. Science and Business Media, LLC, 2008.

27. Otsuka K, Wayman CM, Shape memory materials. Cambridge University Press. 1999.

28. Eren Kaya & İrfan Kaya, A review on machining of NiTi shape memory alloys: the process and post process perspective. The International Journal of Advanced Manufacturing Technology https://doi.org/10.1007/s00170-018-2818-8

29. Mukherjee, Deepmala, P. Srivastava et al., Application of smart materials in civil engineering: A review, Materials Today: Proceedings, https://doi.org/10.1016/j.matpr.2021.03.304

30. Wu MH. Fabrication of nitinol materials and components. Mater Sci Forum 2002;394-395:285–92.

31. Kocich R, Szurman I, Kursa M. The Methods of Preparation of Ti-Ni-X Alloys and Their Forming, Shape Memory Alloys-Processing. Characterization and Applications 2013:28–52. https://doi.org/10.5772/50067.

32. Elahinia MH, Hashemi M, Tabesh M, Bhaduri SB, Manufacturing and processing of NiTi implants: A review (June 2012). doi:10.1016/j.pmatsci.2011.11.001.

33. Novak P, Moravec H, Salvetr P, Pr?ša F, Drahokoupil J, Kopeček J, Karlik M, Kubatik TF. Preparation of nitinol by non-conventional powder metallurgy techniques. Mater Sci Technol 2015;31(15):1886–93. https://doi.org/10.1179/1743284715Y.0000000041.

34. Ibrahim MK, Hamzah E, Saud SN, Bakar ENEA, Bahador A. Microwave sintering effects on the microstructure and mechanical properties of Ti-51at%Ni shape memory alloys.pdf. Int J Miner Metal Mater 2017;24(3):280. https://doi.org/10.1007/s12613-017-1406-5.

35. Morgan N, Wick A, DiCello J, Graham R, Fremont WD. Carbon and oxygen levels in nitinol alloys and the implications for medical device manufacture and durability. 2006;683:821–8. https://doi.org/10.1361/cp2006mst821.

36. ASM. Vacuum Induction Melting, ASM Handbook vol. 15. 2008. p. 1–8. https://doi.org/10.1361/asmhba0005200.

37. Duerig T. NiTi Alloys by Powder Metallurgical Methods Duerig. The 1st Int ’ l Conference on Shape

Memory and Superelastic Technologies, 683 1994:31–6.

38. Otubo J, Rigo OD, Neto CM, Mei PR. The effects of vacuum induction melting and electron beam melting techniques on the purity of NiTi shape memory alloys. Mater Sci Eng A 2006;438-440(SPEC. ISS):679–82. https://doi.org/10.1016/j.msea.2006.02.171.

39. Toro A, Zhou F, Wu MH, Van Geertruyden W, Misiolek WZ. Characterization of non-metallic inclusions in superelastic NiTi tubes. J Mater Eng Perform 2009;18(5- 6):448–58. https://doi.org/10.1007/s11665-009-9410-1.

40. Frenzel J, Neuking K, Eggeler G. Induction melting of NiTi shape memory alloys The influence of the commercial crucible graphite on alloy quality. Materialwissenschaft und Werkstofftechnik 2004;35(5):352–8. https://doi.org/10.1002/mawe.200400725.

41. Tuissi A, Rondelli G, Bassani P. Plasma Arc Melting (PAM) and Corrosion Resistance of Pure NiTi Shape Memory Alloys. Shape Memory Superelasticity 2015;1(1):50–7. https://doi.org/10.1007/s40830-015-0011-6.

42. Schetky LM, Wu MH, Issues in the Further Development of Nitinol Properties And Processing for Medical Device Applications, Memory Corporation, Bethel, Connecticut, USA. doi:10.1361/cp2003mpmd271.

43. Morgan N, Wick A, DiCello J, Graham R, Fremont WD. Carbon and Oxygen Levels in Nitinol Alloys and the Implications for Medical Device Manufacture and Durability. Proceedings of the International Conference on Shape Memory and Superelastic Technologies 2006:821–8. https://doi.org/10.1361/cp2006smst821.

44. Launey M, Robertson SW, Vien L, Senthilnathan K, Chintapalli P, Pelton AR. Influence of microstructural purity on the bending fatigue behavior of VAR-melted superelastic Nitinol. J Mech Behav Biomed Mater 2014;34:181–6. https://doi.org/10.1016/j.jmbbm.2014.02.008.

45. Otubo J, Rigo OD, Moura Neto C, Kaufman MJ, Mei PR. Low carbon content NiTi shape memory alloy produced by electron beam melting. Mater Res 2004;7(2):263–7. https://doi.org/10.1590/S1516-14392004000200008.

46. Castro R. Overview of Conventional Sintering. Sintering 2012;16:129–45. https://doi.org/10.1007/978.

47. Shishkovsky IV, Kuznetsov MV, Morozov YG. Porous titanium and nitinol implants synthesized by SHS/SLS: Microstructural and histomorphological analyses of tissue reactions. Int J Self-Propagating High-Temperature Synthesis 2010;19(2):157–67. https://doi.org/10.3103/S1061386210020123.

48. Bansiddhi A, Sargeant TD, Stupp SI, Dunand DC, Porous NiTi for bone implants: A review (jul 2008). doi:10.1016/j.actbio.2008.02.009.

49. Shishkovsky I, Yadroitsev I, Smurov I. Direct Selective Laser Melting of Nitinol Powder. Physics Procedia 2012;39:447–54. https://doi.org/10.1016/j.phpro.2012.10.060. Elsevier.

50. Salvetr P, Pecenova Z, Školakova A, Novak P. Innovative Technology for Preparation of Seamless Nitinol Tubes Using SHS Without Forming. Metal Mater Trans A: Phys Metal Mater Sci 2017;48(4):1524–7. https://doi.org/10.1007/s11661-017-3974-4.

51. M. K. Stanford, Hot Isostatic Pressing of 60-Nitinol.

52. Fu YQ, Gu YW, Shearwood C, Luo JK, Flewitt AJ, Milne WI. Spark plasma sintering of TiNi nano-powders for biological application. Nanotechnology 2006;17(21):5293–8. https://doi.org/10.1088/0957-4484/17/21/002.

53. Butler J, Tiernan P, Gandhi AA, McNamara K, Tofail SAM. Production of nitinol wire from elemental nickel and titanium powders through spark plasma sintering and extrusion. Journal of Materials Engineering and Performance 2011;20:757–61. https://doi.org/10.1007/s11665-011-9837-z.

54. Krone L, Bram M, Buchkremer HP, St DO, Sch EU, Juelich F. Metal injection molding of shape memory alloys using prealloyed NiTi powders. J Mater Sci 2005;40(16):4231–8. https://doi.org/10.1007/s10853-005-2819-5.

55. Shishkovskii IV, Yadroitsev IA, Smurov IY. Selective laser sintering/melting of nitinol-hydroxyapatite composite for medical applications. Powder Metal Metal Ceram 2011;50(5-6):275–83. https://doi.org/10.1007/s11106-011-9329-6.

56. Krishna BV, Bose S, Bandyopadhyay A. Fabrication of porous NiTi shape memory alloy structures using laser engineered net shaping. J Biomed Mater Res -

Part B Appl Biomater 2009;89(2):481–90. https://doi.org/10.1002/jbm.b.31238.

57. Shiva S, Palani IA, Mishra SK, Paul CP, Kukreja LM. Investigations on the influence of composition in the development of Ni-Ti shape memory alloy using laser based additive manufacturing. Opt Laser Technol 2015;69(1):44–51. https://doi.org/10.1016/j.optlastec.2014.12.014.

58. Pelton AR, Dicello J, Miyazaki S. Optimisation of processing and properties of medical grade Nitinol wire. Minim Invasive Ther Allied Technol 2000;9(2):107–18.

59. Pelton AR, Russell SM, DiCello J. The physical metallurgy of nitinol for medical applications. JOM 2003;55(5):33.

60. James Wamai Mwang et.al, Nitinol manufacturing and micromachining: A review of processes and their suitability in processing medical-grade nitinol. Journal of Manufacturing Processes. 38. 2019. 355–369. https://doi.org/10.1016/j.jmapro.2019.01.003

Optimizing Cutter Leaf Spring Design for Lightweight Vehicles: A Comprehensive Structural and Vibrational Analysis

M. Sunil Kumar*, B. Uday
Rajiv Gandhi University of Knowledge Technologies
R K Valley
Kadapa, Andhra Pradesh
✉ sunilkumar.iiit862@gmail.com

U. Venkatesu
Asst.Prof
Rajiv Gandhi University of Knowledge Technologies
R K Valley
Kadapa, Andhra Pradesh
✉ venkatesu@rguktrkv.ac.in

ABSTRACT

This review paper proThis study utilizes finite element analysis (FEA) to investigate the optimization of cutter leaf spring design for lightweight vehicles. Three materials commonly employed in leaf springs are analyzed for both structural integrity and vibration control: EN45 steel, E-glass/epoxy composite, and carbon Fiber epoxy composite [1, 2, 3]. The analysis focuses on static load performance, evaluating stress distribution, strain response, and total deformation under realistic loading scenarios. Additionally, natural frequencies are calculated to gain preliminary insights into the potential vibration behaviors of each material (further research on dynamic analysis is recommended [4]). By meticulously comparing these results to established material properties, the research sheds light on crucial trade-offs inherent to different materials, particularly their strength-to-weight ratio and potential for vibration mitigation. These findings empower engineers to make informed choices for achieving desired structural integrity, weight efficiency, and improved ride comfort in lightweight vehicles [5]. While acknowledging the limitations of static analysis, this research lays the groundwork for further exploration of dynamic behavior under real-world driving conditions.

KEYWORDS *: Cutter leaf spring, Lightweight vehicle, Finite element analysis (FEA), Ansys, SolidWorks.*

INTRODUCTION

Leaf springs are a critical component within the suspension systems of light trucks and automobiles. They play a pivotal role in vehicle dynamics by effectively absorbing static loads, maintaining ride height, and contributing to overall handling characteristics [6]. However, traditional steel leaf springs can contribute significantly to vehicle weight, hindering fuel efficiency and overall performance. This weight reduction becomes even more crucial in the design of lightweight vehicles, where every kilogram saved translates to improved fuel economy and potentially extended range [7]. Cutter leaf springs offer a specific design variation with a tapered cross-section. Compared to traditional parabolic or multi-leaf configurations, cutter springs have the potential to reduce weight while maintaining functionality [8]. This research leverages finite element analysis (FEA) within ANSYS software [9] to conduct a comprehensive analysis of three commonly employed materials for cutter leaf springs:

- EN45 steel: A high-strength steel commonly used in leaf spring applications due to its favorable strength and durability characteristics [10].
- E-glass/epoxy composite: A composite material consisting of E-glass fibers embedded in an epoxy resin matrix. Composites offer potential weight savings while maintaining stiffness [11].
- Carbon fiber epoxy composite: Another composite material utilizing carbon fibers for superior stiffness and strength-to-weight ratio compared to E-glass/epoxy [12].

By focusing on both structural integrity and vibration control characteristics, the research aims to achieve the following objectives:

- Evaluate Static Load Performance: Analyze stress distribution, strain response, and deformation under static load conditions to ensure design requirements are met and failure is avoided.
- Assess Vibrational Behaviour: Analyze the natural frequencies of each leaf spring model to gain preliminary insights into potential vibration control characteristics.
- Compare Material Performance: Compare the results obtained for each material to their known properties, considering both static and dynamic loading scenarios. This comparison will guide material selection based on specific performance requirements for lightweight vehicles.

The findings from this research will be of considerable value to engineers working on leaf spring design for lightweight vehicles. By understanding the interplay between static load performance and potential vibrational behaviour of various materials, they can make informed choices to achieve desired:

- Structural integrity: The analysis ensures the leaf spring can withstand static loads encountered during operation without failure [13].
- Weight efficiency: Selecting a material with a favorable strength-to-weight ratio optimizes overall vehicle performance through weight reduction [14].
- Improved ride comfort: A well-designed leaf spring contributes to proper ride height, handling, and minimization of vibrations transmitted to the passenger compartment [15].

This research builds upon existing knowledge in leaf spring design for lightweight vehicles. Studies have explored the potential of composite materials to achieve weight reduction while maintaining or improving stiffness compared to traditional steel leaf springs [5, 6]. However, a comprehensive analysis that considers both structural integrity and vibration control characteristics using FEA is necessary to optimize cutter leaf spring design for this specific application. This research aims to fill this gap by providing a detailed comparison of material performance through FEA simulations.

LITERATURE REVIEW

Leaf springs have been a cornerstone component within the suspension systems of light trucks and automobiles for a considerable period [16]. They play a critical role in vehicle dynamics by effectively managing static loads, maintaining optimal ride height, and influencing overall handling characteristics [16]. However, a significant drawback associated with traditional steel leaf springs is their weight, which can hinder fuel efficiency and overall vehicle performance [17]. This weight reduction becomes even more crucial in the design of lightweight vehicles, where minimizing weight translates directly to improved fuel economy and potentially extended range [17].

Researchers have actively explored various strategies to optimize leaf spring design for lightweight vehicles. A promising approach involves the utilization of composite materials. These materials, typically composed of fibers embedded within a resin matrix, offer the potential for significant weight savings while maintaining or even enhancing stiffness compared to traditional steel [18, 19].

E-glass/epoxy composites are a popular choice due to their affordability and well-established manufacturing techniques [19]. Studies conducted by Rana and Faizal (2017) analyzed the design and performance of composite leaf springs for lightweight vehicles using E-glass/epoxy composites [19]. Their findings demonstrated the feasibility of achieving weight reduction while ensuring adequate structural integrity. However, E-glass/epoxy composites might not offer the absolute highest stiffness-to-weight ratio compared to other options [20].

Carbon fiber epoxy composites offer superior stiffness and a considerably improved strength-to-weight ratio when compared to E-glass/epoxy [20, 21]. Achamyeleh et al. (2012) investigated the design and analysis of mono composite leaf springs fabricated from carbon fiber epoxy for lightweight vehicles [21]. Their research highlighted the potential for substantial weight reduction while achieving the necessary structural performance. However, carbon fiber composites can be more expensive than E-glass/epoxy, and their manufacturing processes might be more complex [22].

Beyond material selection, researchers have also investigated the influence of leaf spring design itself on performance. Cutter leaf springs, with their tapered cross-section, offer potential weight savings compared to traditional parabolic or multi-leaf configurations while maintaining functionality [23].

While these studies provide valuable insights, a comprehensive analysis that considers both structural integrity and vibration control characteristics using finite element analysis (FEA) is necessary for optimal cutter leaf spring design. This research aims to address this gap by conducting a detailed FEA analysis of cutter leaf springs employing EN45 steel, E-glass/epoxy composite, and carbon fiber epoxy composite. By evaluating both static load performance and vibrational behavior, this research will provide valuable information for engineers working on leaf spring design for lightweight vehicles, ultimately contributing to the development of more efficient and performant transportation solutions

METHODOLOGY

This research employs finite element analysis (FEA) to comprehensively evaluate the performance of cutter leaf spring designs for lightweight vehicles. The analysis focuses on three commonly used materials, aiming to identify the material that offers the optimal balance of weight reduction and structural integrity for this specific application

Computer-Aided Design (CAD) Modeling

SolidWorks software will be utilized to develop precise 3D models of the cutter leaf springs for each material. These models will incorporate the specific dimensions and characteristic tapered cross-section of cutter leaf springs

LEAF SPRING SPECIFICATIONS

Table no 1: Dimensions

Sr. No	Parameter Name	Value(mm)
1	Leaf Span	660.4
2	No. Of Full-length leaves	1
3	No.of Graduate Leaves	3
4	No. of Leaves	4
5	Width	44.45
6	Thickness	6.35
7	Eye diameter with bushing	14.28
8	Eye diameter with bushing	17.46

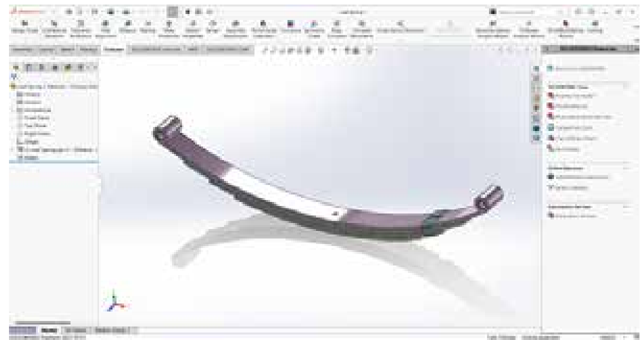

Figure 1 Leaf spring Design model

Table 2: Material properties of EN45(Steel) [24]

Steel	EN45 A
Young Modulus [E]	204 Gpa
Poisson Ratio	0.266
Ultimate tensile strength	1272 MPa
Yield Tensile strength	1158 MPa
Density	7850 Kg/m^3

Table 2: Material properties of Glass Epoxy Composite [24]

Properties	Glass epoxy
Density (kg/m3)	2000
Yong's Modulus E (GPa)	50
Longitudinal tensile fracture strength (MPa)	800
Poisson's Ratio	0.3
Transverse tensile strength (MPa)	40
Shear strength (MPa)	30
Shear Modulus (GPa)	5.6

Table 2: Material properties of Carbon/Epoxy Composite [24]

N	Property	Symbol	Units	Carbon/ Ep oxy
1	Youngs modulus	E	GPa	190

2	Transverse Modulus	E22	GPa	7.7
3	Shear Modulus	G12	GPa	4.2
4	Poisson's Ratio	υ	-----	0.36
5	Density	ρ	Kg/m^3	1600
6	Longitudinal Tensile strength	St1	Mpa	870
7	Transverse Tensile strength	St2	Mpa	540
8	Shear strength	Ss	Mpa	30

STRUCTURAL ANALYSIS

Finite Element Modeling: A structured approach is adopted for the FEA modeling process, building upon the established CAD models:

Mesh Generation: The CAD models generated in SolidWorks will be exported to a pre-processing software for mesh generation. Appropriate element types, such as tetrahedral or hexahedral elements, will be chosen for accurate representation of complex geometries. Mesh refinement will be conducted in critical areas, such as around the bolt eyes and regions with anticipated high stress concentrations, to capture the behavior with greater precision.

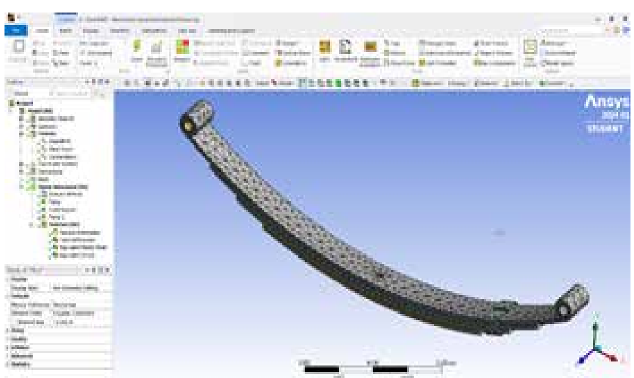

Figure 2 Meshing

Material Properties and Boundary Conditions: Material properties, including Young's modulus, Poisson's ratio, and density, will be assigned to each model based on established data sources or experimental characterization. The leaf spring models will be fixed at one end, simulating the attachment to the vehicle chassis. A static load will be applied at the free end, replicating the load transferred from the axle during vehicle operation. The chosen load magnitude will represent realistic operating conditions for lightweight vehicles.

Material Behavior and Contact: Linear elastic material behavior will be assumed for the steel model, as it is a common and valid first approximation for static load analysis of leaf springs. Material properties for the composite models (E-glass/epoxy and carbon fiber epoxy) will be incorporated using appropriate material models within the FEA software to account for their potentially non-linear behavior. Frictional contact will be defined between the leaf spring and any simulated mating surfaces, such as the axle or shackles, to account for potential frictional effects.

STEEL EN45

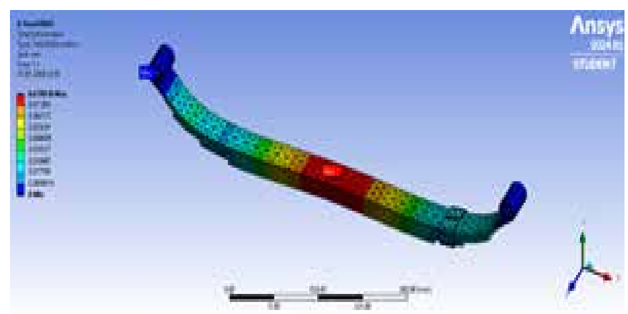

Figure 3 Total Deformation

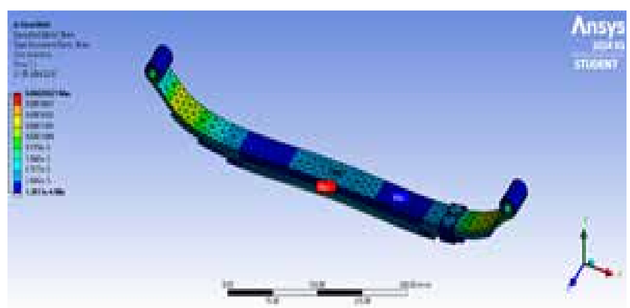

Figure 4 Equivalent Elastic strain

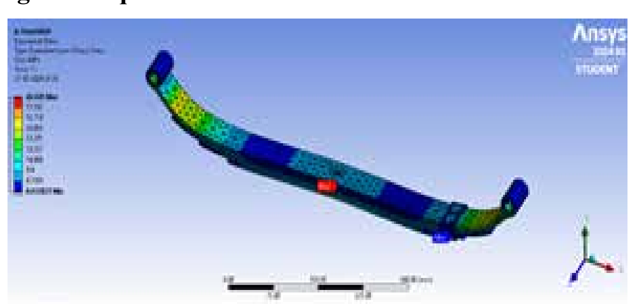

Figure 5 Equivalent Stress

E- GLASS EPOXY COMPOSITE

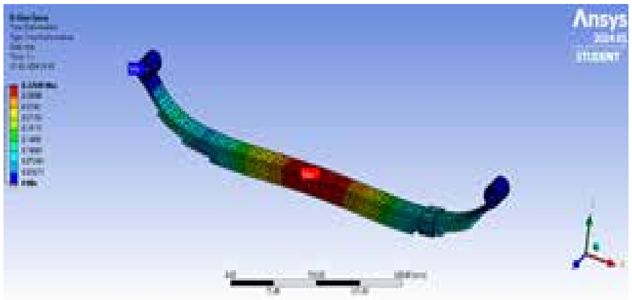

Figure 6 Total Deformation

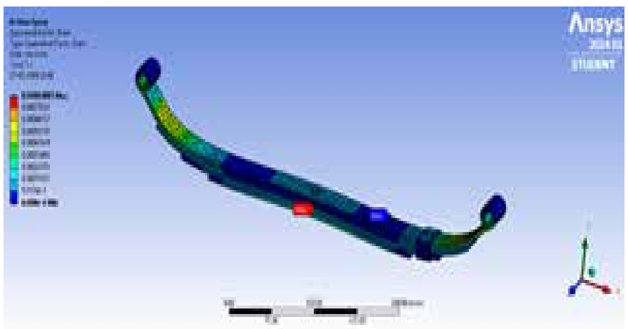

Figure 7 Equivalent Elastic strain

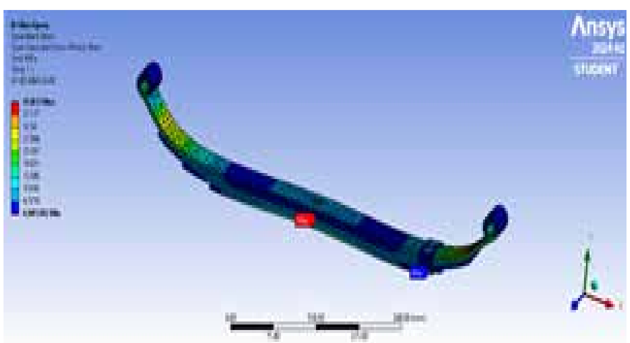

Figure 8 Equivalent Stress

Cabon Fiber Epoxy

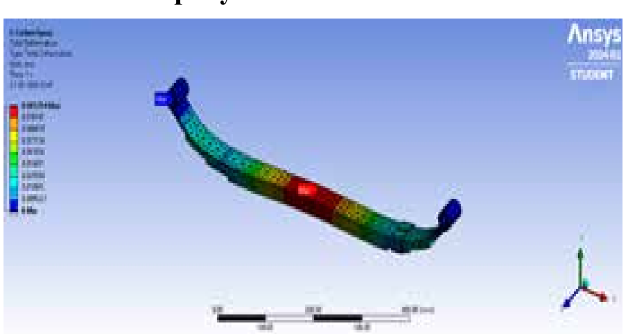

Figure 9 Total deformation

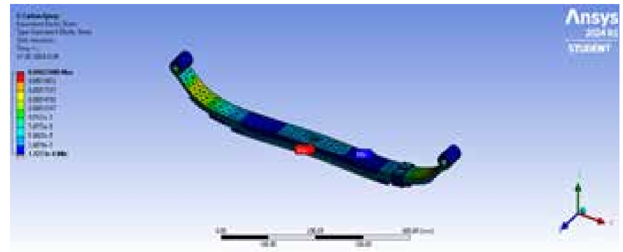

Figure 10 Equivalent Elastic strain

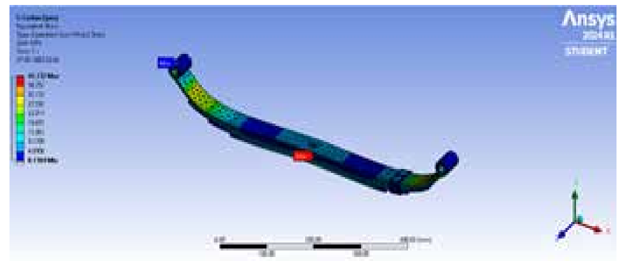

Figure 11 Equivalent Stress

Vibrational Analysis

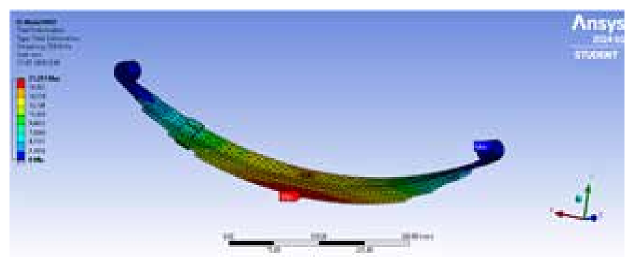

Figure 12 EN45 Total Deformation

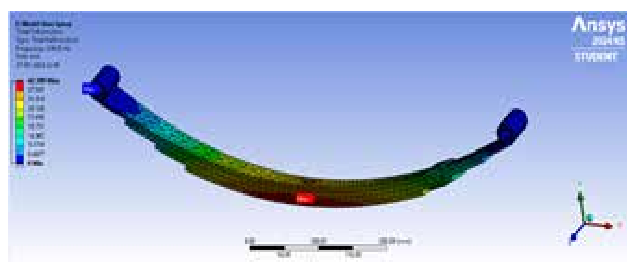

Figure 13 Glass Epoxy Total Deformation

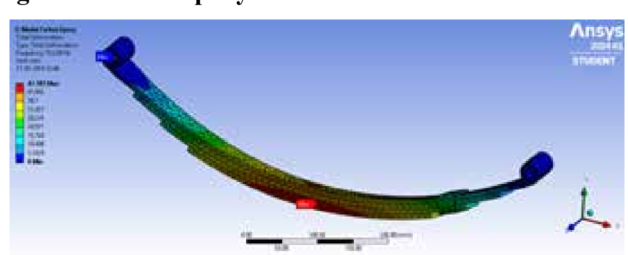

Figure 14 Carbon Epoxy Total deformation

Modal Analysis

Material	Total Deformation (mm)	Directional Deformation (mm)
Steel EN45	21.291	0.7273
Glass Epoxy	42.189	1.4361
Carbon Epoxy	47.185	1.601

Frequency [Hz]

Material	1	2	3	4	5	6
Steel EN45	259.42	375.65	675.89	904.97	1127.6	1298.3
Glass Epoxy	254.05	370.27	663.37	884.38	1107.5	1271
Carbon Epoxy	552.49	811.13	1448.2	1917.3	2421.5	2762.3

Simulation Results

Material	Total Deformation (mm)	Equivalent elastic strain m/m)	Equivalent stress (MPa)	Load (lbs.)
Steel EN45	0.0799	0.0002	42.045	1000
E-Glass Epoxy	0.3260	0.0008	41.813	1000
Carbon fiber Epoxy	0.0857	0.000241	41.332	1000

RESULTS AND DISCUSSION

This study employed finite element analysis (FEA) to investigate the performance of cutter leaf spring designs for lightweight vehicles, focusing on three commonly used materials: EN45 steel, E-glass/epoxy composite, and carbon fiber epoxy composite.

Key Findings

- All materials (EN45 steel, E-glass/epoxy composite, and carbon fiber epoxy composite) demonstrated adequate static load capacity under a simulated 1000 lb load, ensuring their suitability for the intended application in lightweight vehicles.
- Steel exhibited the lowest total deformation (0.0799 mm), followed by Carbon Fiber Epoxy (0.0857 mm) and E-glass Epoxy (0.3260 mm). This suggests Steel offers the greatest stiffness under static loads.
- Equivalent stress values were comparable across all materials (around 42 MPa), indicating similar strength under the applied load.
- Modal analysis revealed differences in natural frequencies, with Steel having the lowest values, followed by E-glass Epoxy and then Carbon Fiber Epoxy. This suggests Steel may initially resist vibrations better; however, further investigation is necessary for all materials under real-world driving conditions.

Implications for Lightweight Vehicle Design:

- Material Selection: The optimal material selection hinges on the specific priorities for lightweight vehicle design.
    - o Strength-to-Weight Ratio: Carbon Fiber Epoxy offers the most favorable ratio, enabling significant weight reduction while maintaining structural integrity.
    - o Cost-Effectiveness: E-glass Epoxy is a more economical option compared to Carbon Fiber Epoxy.
    - o Manufacturing Complexity: Steel is a well-established material with simpler manufacturing processes when compared to composites.
- Vibration Control: While the initial findings provide insights, further dynamic analysis is recommended for all materials to fully understand and optimize vibration mitigation strategies in the final design.

CONCLUSION

This FEA analysis equips engineers with valuable data to guide material selection and optimization of cutter leaf spring design for lightweight vehicles. The findings highlight the trade-offs between different materials and their impact on structural integrity, weight reduction, and potential vibration control.

- **Steel:** While offering the greatest stiffness under static loads, Steel's weight might hinder weight reduction efforts.
- **Composite Materials:** E-glass/epoxy and Carbon Fiber Epoxy offer significant weight-saving potential compared to Steel. However, their

dynamic behavior requires further investigation for optimal performance.

By considering these key findings and their implications, engineers can make informed decisions for material selection and optimize cutter leaf spring design for lightweight vehicles, ultimately contributing to improved fuel efficiency and overall vehicle performance. This research paves the way for further exploration of dynamic behaviour and real-world testing to validate the FEA results and refine the design for optimal performance in lightweight vehicles.

REFERENCES

1. Achamyeleh, H. R., Iqbal, M. A., Sapuan, S., & Norrhamdan, M. N. (2012). Design And Analysis of Mono Composite Leaf Spring for Light Weight Vehicles. International Journal of Engineering and Research, 1(2), 169-174.
2. Rana, S., & Faizal, M. (2017). Design and analysis of composite Leaf Spring for light Weight Vehicle. International Journal of Advanced Research in Engineering Sciences and IT (IJARES), 5(2), 2278-0149.
3. Babu, G. J., & Prabhu, G. M. (2016). Design considerations and analysis of leaf spring using composite materials. Materials Today: Proceedings, 14(2), 1133-1143.
4. Arora, V., Bhushan, G., & Aggarwal, M. (2015). Static structural CAE analysis of symmetrical 65Si7 leaf springs in automotive vehicles. Engineering Solid Mechanics, 3, 59-74.
5. Babu, G. J., & Prabhu, G. M. (2016). Design considerations and analysis of leaf spring using composite materials. Materials Today: Proceedings, 14(2), 1133-1143
6. Milliken, W. F., & Milliken, D. L. (2002). Race car vehicle dynamics. Society of Automotive Engineers (SAE International)
7. Alola, O. O., & Hadi, M. J. (2012). A review of lightweight materials and structures for electric vehicles. Renewable and Sustainable Energy Reviews, 16(5), 2295-2302.
8. Gebremeskel, S. (2013). Design, Simulation, and Prototyping of Single Composite Leaf Spring for Light Weight Vehicle. Global Journal of Research In Engineering, 12.
9. Madenci, E., & Guven, I. (2007). The Finite Element Method and Applications in Engineering Using ANSYS. . https://doi.org/10.1007/978-0-387-28290-9.
10. Avşar, T., & Gürcü, S. (2011). Investigation of the effects of different materials and cross-section shapes on leaf spring performance. Materials & Design, 32(2), 752-758.
11. Rana, S., & Faizal, M. (2017). Design and analysis of composite Leaf Spring for light Weight Vehicle. International Journal of Advanced Research in Engineering Sciences and IT (IJARES),5(2), 2278-0149.
12. Achamyeleh, H. R., Iqbal, M. A., Sapuan, S., & Norrhamdan, M. N. (2012). Design And Analysis of Mono Composite Leaf Spring for Light Weight Vehicles. International Journal of Engineering and Research, 1(2), 169-174
13. Babu, G. J., & Prabhu, G. M. (2016). Design considerations and analysis of leaf spring using composite materials. Materials Today: Proceedings, 14(2), 1133-1143.
14. Rao, G. A., & Prasad, K. M. (2014). Optimum design of a composite leaf spring for a light commercial vehicle. Materials & Design, 54, 190-198.
15. Heißing, F., & Erlichman, A. (2003). Chassis Handbook: Fundamentals, Driving Dynamics, Components, Mechatronics (2nd ed.). Springer
16. Milliken, W. F., & Milliken, D. L. (2002). Race car vehicle dynamics. Society of Automotive Engineers (SAE International)
17. Alola, O. O., & Hadi, M. J. (2012). A review of lightweight materials and structures for electric vehicles. Renewable and Sustainable Energy Reviews, 16(5), 2295-2302.
18. Rana, S., & Faizal, M. (2017). Design and analysis of composite Leaf Spring for light Weight Vehicle. International Journal of Advanced Research in Engineering Sciences and IT (IJARES), 5(2), 2278-0149.

19. Achamyeleh, H. R., Iqbal, M. A., Sapuan, S., & Norrhamdan, M. N. (2012). Design And Analysis of Mono Composite Leaf Spring for Light Weight Vehicles. International Journal of Engineering and Research, 1(2), 169-174.

20. Babu, G. J., & Prabhu, G. M. (2016). Design considerations and analysis of leaf spring using composite materials. Materials Today: Proceedings, 14(2), 1133-1143.

21. Heißing, F., & Erlichman, A. (2003). Chassis Handbook: Fundamentals, Driving Dynamics, Components, Mechatronics (2nd ed.). Springer.

22. Bader, M. (2002). Selection of composite materials and manufacturing routes for cost-effective performance. Composites Part A-applied Science and Manufacturing, 33, 913-934. https://doi.org/10.1016/S1359-835X(02)00044-1.

23. Avşar, T., & Gürcü, S. (2011). Investigation of the effects of different materials and cross-section shapes on leaf spring performance. Materials & Design, 32(2), 752-758

24. Design and Analysis of Composite Leaf Spring using composite material for light vehicle Sandip R. Mundale[1], Prof.D.B.Pawar[2], Prof.D.J.Verma[3],ijred

Reliability Analysis of Repairable Systems: A Case Study from Indian Industry

Sarfraz Ali Quadri*, Shrikrishna B Pawar
Research Scholar
Department of Mechanical Engineering
JNEC, MGM University
Aurangabad, Maharashtra
✉ sarfrazali.research@gmail.com

Varsha Jadhav
Assistant Professor
AI&DS Department
VIT Pune
Maharashtra
✉ drvarshajadhav22@gmail.com

Dhananjay R Dolas
Associate Professor
Mechanical Department
JNEC, MGM University
Aurangabad, Maharashtra
✉ drdolasjnec@gmail.com

ABSTRACT

The pandemic has had a severe impact on the industrial sector, leading to shutdowns and potential closure of Indian MSMEs due to financial losses. In the post-pandemic world, reliable production is essential due to limited resources. Industries globally, particularly MSMEs, face challenges in achieving productivity and customer satisfaction while meeting the demand for reliable products at a low cost. This highlights the importance of reliability engineering in complex systems and their economics. Reliability centered assessments have proven to be effective in extending the lifespan of industrial systems by analyzing repairable and non-repairable subsystems and identifying critical subsystems responsible for most failures. Reliability analysis is important for ensuring reliability of industrial systems. Engineers can improve system performance and reliability, saving money and improving customer satisfaction. Reliability analysis helps determine optimal maintenance schedules, minimizing unplanned downtime. Understanding system reliability can lead to significant benefits for organizations. The objective of this research article is to furnish a thorough examination of the estimation of reliability for a repairable industrial system. The manuscript outlines the steps involved, starting from the collection of data, performing trend tests, and determining the best fit distribution for parameter estimation and reliability analysis. This comprehensive guide will prove invaluable to reliability and maintenance engineers, as well as decision makers, enabling them to make optimal decisions and improve maintenance schedules.

KEYWORDS : *Reliability analysis, Complex repairable system, System reliability, Failure data, Life data, Weibull etc.*

INTRODUCTION

The concept of "Reliability" is inherently subjective in nature, as it has been defined multiple times by various authors in accordance with specific applications. According to the Merriam-Webster dictionary, it is defined as "The quality or state of being reliable." In other literature, it has been defined as "the probability that a component or system will perform a required function for a given period of time when used under stated operating conditions" (Charles Ebeling, 1997). In today's world, reliability analysis holds significant importance due to the presence of numerous complex systems, such as communication devices (e.g., mobile phones, laptops) and transportation means (e.g., cars, trains, aeroplanes), on which we heavily rely to efficiently and promptly complete our tasks. The failure of any of these systems to perform as expected can have severe repercussions on the functioning of our society on a daily basis. Hence, it is crucial for these complex systems to be as reliable as possible. The manufacturers of these devices and complex systems must prioritize reliability right from the design stage. They need to comprehend the critical sub-components involved in the assembly and their interdependencies, as well as the various failure modes associated with their product and the maintenance strategies to mitigate any unwanted breakdowns or failures. Original Equipment Manufacturers (OEMs) are well aware of the significance of reliability studies in enhancing their product cycles, and they conduct dedicated reliability studies to anticipate and address any unforeseen events. The purpose of this study is to review existing research and case studies on reliability analysis of complex repairable systems and to outline a stage-wise roadmap for future reliability studies.

Reliability holds significant importance for both manufacturers and consumers alike. Manufacturers must ensure that their products are dependable in order to meet customer expectations and prevent any need for recalls. On the other hand, consumers desire assurance that the products they purchase will perform as anticipated. Various methods exist for measuring reliability, with one common approach being the utilization of a failure rate. The failure rate represents the probability of a product failing within a specified time period. For instance, a product with a failure rate of 1% indicates a 1% likelihood of failure within one year. The analysis of reliability always commences with the initial step of meticulous and well-planned data collection, typically gathering failure data and Time to Failure (TTF) in the case of repairable industrial systems. The entire analysis hinges upon the fundamental assumption that the collected data is independent and identically distributed (iid) over time; otherwise, drawing improper conclusions that fail to comprehensively interpret the system under scrutiny may occur. The simplest way to verify the iid is through a graphical trend test, followed by fitting the TTF data with a probability distribution. Ultimately, the parameter estimation of the probability distribution can be conducted by employing a best-fit distribution with the aid of various available software tools.

LITERATURE REVIEW

Over the years, numerous international and national researchers have conducted extensive investigations into the various complex repairable industrial systems, focusing specifically on the aspects of Reliability. The primary purpose of utilizing the Reliability approach is to analyze complex repairable industrial systems and plan their operational life and maintenance strategies. In the context of the present study, a comprehensive examination of reliability analysis stages has been undertaken, considering the viewpoint of beginners in the field. Moreover, the literature review includes several noteworthy research articles. For instance, the work by MarcantonioCatelani et al. [1] explores parameter estimation methods for failure rate distributions, such as Least Square Estimation and Maximum Likelihood Estimation, while also investigating two types of field data to identify the most appropriate fitting distribution. The study emphasizes the versatility of the Weibull distribution in modeling various failure rate functions. Similarly, JavadBarabady et al. [2] delves into the significance of reliability in the planning, design, and operation of engineering systems, with a particular focus on the mining industry. The authors present a case analysis of the reliability and maintainability of crushing plants in the Jajarm bauxite mine in Iran. By dividing the crushing plants into seven subsystems, they conduct reliability analysis for each subsystem using failure data. The findings demonstrate the usefulness of reliability and maintainability analysis in determining maintenance intervals and organizing maintenance activities. Additionally, the analysis of total downtime, breakdown frequency, reliability, and maintainability characteristics of different subsystems reveals a decrease in the reliability of crushing plants 1 and 2 as the mission time increases.

In another study, Dolas D. R. et al. [3] specifically focus on the reliability analysis of the cooling system water pump of diesel engines used in compressor applications. The researchers employ Weibull distribution for statistical calculations and present the results in graphical form. They also conduct Pareto analysis to identify the failure frequency of critical components. The findings provide valuable insights for maintenance policies and strategies to prevent breakdowns and downtime of the cooling system water pump. Ultimately, the paper concludes that determining the individual failure rates of water pump parts and their contribution to overall reliability is essential. Lastly, Vivek Kumar et al. [4] concentrate on analyzing the failure times of a boiler in a thermal power plant to identify critical failure expectancy and system reliability. The study utilizes Weibull probability plot and statistical analysis to perform reliability and maintainability analysis, with the results presented in graphical form. The paper also discusses the method for selecting the best analysis mode and the equations employed to determine the mean time to failure and reliability of the two-parameter Weibull distribution. This study is significant as sudden failures of any power plant boiler component lead to production losses and high maintenance costs, consequently increasing the production cost of electricity unnecessarily. In their study, Dolas& et al. [5] conduct a reliability analysis of the cooling system of a diesel engine used for compressor applications. The authors utilize time-to-failure data and the two-parameter Weibull distribution to estimate various reliability parameters such as availability, mean time between failure, failure rate, and failure density. To estimate these parameters, the authors employ both the analytical least square method and Minitab 16.1R software. The findings of this study have practical implications for the design, manufacturing, and modification of cooling system components.

Quadri et al.present a roadmap for reliability analysis of complex repairable systems, stressing the importance of data collection, validation, and Weibull distribution utilization [6]. Barabady and Kumar (Year) conduct a reliability and availability analysis of a crushing plant in a Bauxite Mine, highlighting critical subsystems and maintenance strategies [7]. Rezvanizaniani et al. (Year) focus on field failure data collection and reliability analysis in a passenger train company, identifying wheel sets as critical subsystems [8]. Kumar et al. (Year) analyze boiler failure times at a thermal power plant, emphasizing Weibull probability plots for reliability assessment [9]. Naseri et al. (Year) review Arctic offshore operating conditions and their impact on reliability, availability, and maintainability of offshore facilities [10].In this section we have tried to accumulate the various reliability studies done across multiple domains like mining industries, locomotive manufacturing industries, diesel engineering manufacturing industries and thermal power plants. The literature survey also focuses on various life distribution and their suitability for various complex repairable system, which emphasizes the versatility of Weibull distribution. Also a comprehensive comparison of various methodologies for reliability systems suggest a common and fundamental approach well presented in the study of JavadBarabady&Uday Kumar [7] which is elaborated further using the case study from the Indian industry. The fundamental approach for the modeling of repairable systems is demonstrated sequentially in Figure 1 for the purpose of reliability assessment. This figure provides a comprehensive flowchart for the identification of models and serves as the primary framework for the examination of the failure and repair data pertaining to mining equipment.

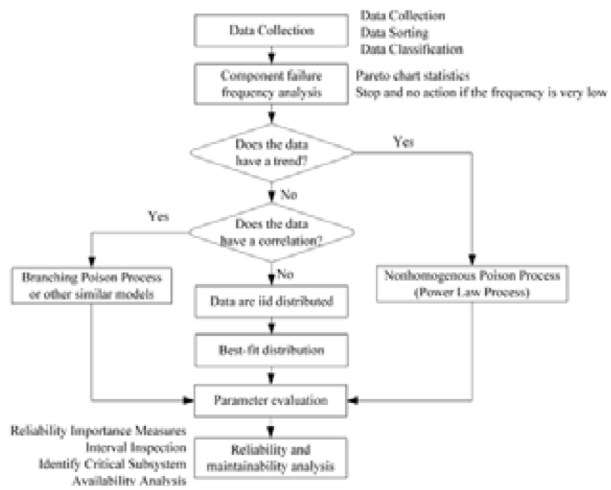

Figure 1 Process of repairable system reliability analysis [7]

CASE STUDY

For the current study, the failures data of a Borewell compressor diesel engine water pump is considered from the engine log book for three years [3] and Process of repairable system reliability analysis[7]

Step 1-Data Collection: Time to Failure of 50 pumpsis collected for a span of 3 years from the log book which is as follows:

1895, 2000, 2106, 628, 681, 892, 2904, 2961, 3172, 3341, 3789, 365, 495, 1250, 1276, 1338, 1556, 1633, 1668, 915, 950, 1091, 1100, 4231, 4368, 4596, 720, 4788, 1135, 1194, 2346, 2434, 886, 1854, 1876, 2440, 3941, 4812, 1687, 4992, 2109, 2570, 801, 2607, 2628, 2117, 2470, 2174, 2547, 2646.

Step 2-Identifying Distribution:

Identifying distribution is both art & science as it requires proper knowledge and understanding of theoretical distributions and failure modes and process. One suggested approach is to construct a histogram of failure times, compute descriptive statistics and construct a probability plot. This approach is presented here;

For constructing the histogram shown in figure 2, one important aspect is to select optimum bin size. Here we have used the Sturges Rule To select optimum bin intervals. i.e.

$$K = [\,1 + 3.3\; Log_{10}\; n]$$

$$K = [\,1 + 3.3\,(1.69)] = 6.67$$

So optimal bin size should be taken as 7, as per Sturges Rule.

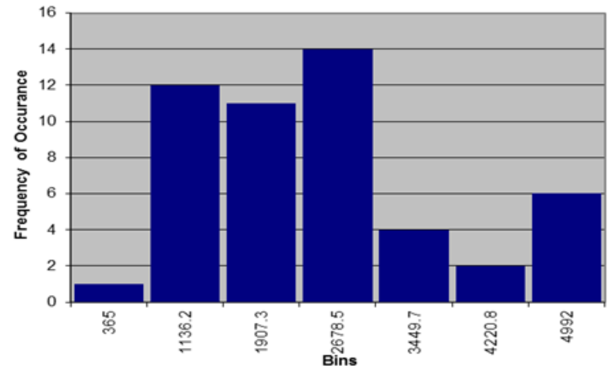

Figure 2 Histogram of time to failure data

The bin size and frequency is represented in table 01 and the Descriptive Statistics in table 02.

Table 1 Bin size and frequency

Bin	365	1136	1907	2679	3450	4221	4992
Frequency	1	12	11	14	4	2	6

Table 2 Descriptive Statistics

Mean	Standard Error	Median	Standard Deviation	Sample Variance	Kurtosis	Skewness	Range	Count	Confidence Level (95.0%)
2179.5	**176.5329**	**2053**	**1248.276**	**1558193**	**-0.27536**	**0.717561**	**4627**	**50**	**354.7561**

Step 3-Least Square Curve Fitting

Numerous methods exist for estimating parameters to fit a lifetime distribution to a dataset, with one of the most significant being the least squares method. This statistical approach minimizes the sum of squared residuals between observed and predicted values by fitting a curve to the data points. Widely used across various disciplines like statistics, engineering, and economics, the least squares method is particularly adept at fitting linear or simple polynomial curves to data. However, it can also be extended to more complex curves while retaining its fundamental principles.

$$y = mx + c$$

Where, $m = \frac{N.\sum(xy) - \sum x \sum y}{N\sum x^2 - (\sum x)^2}$ $\quad c = \frac{\sum y - m\sum x}{N}$

Table 3 Least Square Method

Failure	Time to Failure	F(ti)	ln(ti)	ln{ln[1/1-F(ti)]}	Failure	Time to Failure	F(ti)	ln(ti)	ln{ln[1/1-F(ti)]}
1	365	0.0139	5.8999	-4.2697	26	2106	0.5099	7.6525	-0.3380
2	495	0.0337	6.2046	-3.3723	27	2109	0.5298	7.6540	-0.2817
3	628	0.0536	6.4425	-2.8993	28	2117	0.5496	7.6578	-0.2261
4	681	0.0734	6.5236	-2.5738	29	2174	0.5694	7.6843	-0.1712
5	720	0.0933	6.5793	-2.3239	30	2346	0.5893	7.7605	-0.1167

6	801	0.1131	6.6859	-2.1201	31	2434	0.6091	7.7973	-0.0625
7	886	0.1329	6.7867	-1.9474	32	2440	0.6290	7.7998	-0.0086
8	892	0.1528	6.7935	-1.7970	33	2470	0.6488	7.8120	0.0454
9	915	0.1726	6.8189	-1.6634	34	2547	0.6687	7.8427	0.0995
10	950	0.1925	6.8565	-1.5429	35	2570	0.6885	7.8517	0.1539
11	1091	0.2123	6.9948	-1.4328	36	2607	0.7083	7.8660	0.2088
12	1100	0.2321	7.0031	-1.3312	37	2628	0.7282	7.8740	0.2644
13	1135	0.2520	7.0344	-1.2367	38	2646	0.7480	7.8808	0.3209
14	1194	0.2718	7.0851	-1.1482	39	2904	0.7679	7.9738	0.3787
15	1250	0.2917	7.1309	-1.0647	40	2961	0.7877	7.9933	0.4381
16	1276	0.3115	7.1515	-0.9855	41	3172	0.8075	8.0621	0.4995
17	1338	0.3313	7.1989	-0.9101	42	3341	0.8274	8.1140	0.5634
18	1556	0.3512	7.3499	-0.8379	43	3789	0.8472	8.2399	0.6306
19	1633	0.3710	7.3982	-0.7686	44	3941	0.8671	8.2792	0.7020
20	1668	0.3909	7.4194	-0.7017	45	4231	0.8869	8.3502	0.7791
21	1687	0.4107	7.4307	-0.6371	46	4368	0.9067	8.3821	0.8639
22	1854	0.4306	7.5251	-0.5743	47	4596	0.9266	8.4329	0.9600
23	1876	0.4504	7.5369	-0.5132	48	4788	0.9464	8.4739	1.0739
24	1895	0.4702	7.5470	-0.4536	49	4812	0.9663	8.4789	1.2206
25	2000	0.4901	7.6009	-0.3953	50	4992	0.9861	8.5156	1.4532

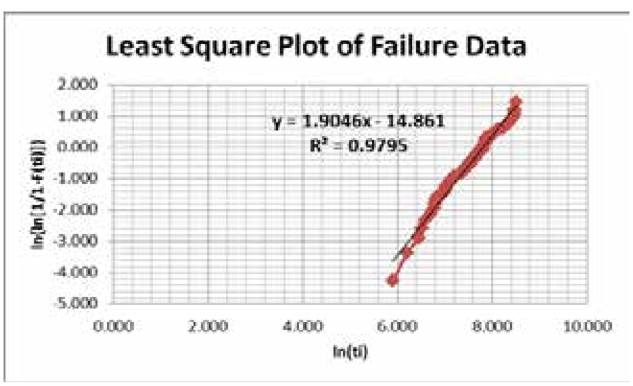

Figure 3 Least Square Plot of Failure Data

Intercept = c = -14.861, Slope = M = 1.9046, Index of Fit = r2 = 0.9795. The index of fit (0.9795)

indicates a good fit.

Step 4-Probability Plot and Parameter Evaluation

The analysis conducted using PTC Windchill Quality Solution 10.2 software indicates that both 3-parameter and 2-parameter Weibull distributions fit the data well. However, due to differing estimation methods, their ranking varies. Other distributions like normal, log-normal, gamma, and exponential do not fit the data adequately, showing lower correlation coefficients. The 3-parameter Weibull distribution exhibits the best fit, with nearly unity correlation coefficient. Figure 04 visually confirms these findings.

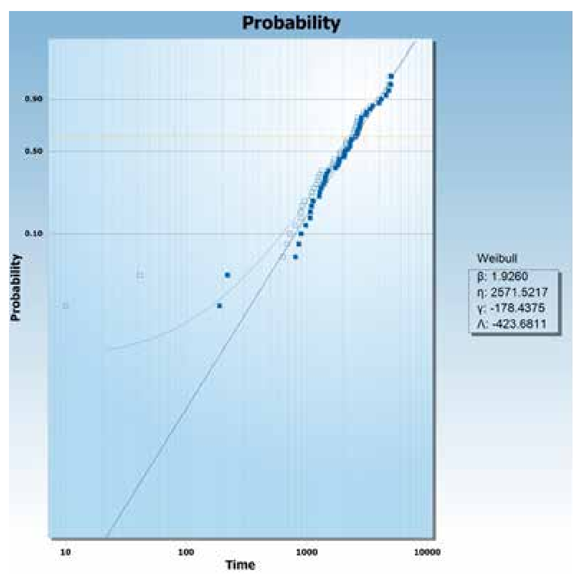

Figure Probability Plot of Failure Data

The equation for the 3-parameter Weibull cumulative density function, cdf, is given by:

$$F(t) = 1 - e^{-(\frac{t-\gamma}{\eta})^{\beta}}$$

This is also referred to as unreliability and designated as Q (t) by some authors, recalling that the reliability function of a distribution is simply one minus the cdf, the reliability function for the 3-parameter Weibull distribution is then given by:

$$R(t) = e^{-(\frac{t-\gamma}{\eta})^{\beta}}$$

Similarly, with the given equation we can calculate reliability of the system at any specific time, for example the reliability of the said water pump at 1500 hours, (β = 1.9260, η = 2571.5217, γ = -178.43)

$$R(t = 1500) = e^{-(\frac{1500-(-178.43)}{2571.5217})^{1.9260}}$$

$$R(t = 1500) = 0.6640$$

$$R(t = 1500) = 66.40\ \%$$

CONCLUSION

The paper provides a comprehensive study of reliability estimation of a repairable industrial system. It covers the stages of reliability analysis from data and emphasizes the importance of proper and well-planned analysis. It practically presents the stages with a case of the failures data of a bore-well compressor diesel engine water pump from an Indian manufacturer. The results highlight the best-fit distribution for the failure data of pump as three parameter Weibull since the correlation coefficient is almost unitary and higher than the other distributions. The later part of the research article also presents a case of reliability estimation using 3 parameter Weibull analysis for the pump at a given specific time in its working life i.e. at 1500 hours of working the system shows a reliability of 66.40%. The article will act as a beginner's guide of budding reliability and maintenance engineers and practitioners.

REFERENCES

1. Catelani, M., Ciani, L., Guidi, G., &Venzi, M.. (2016). Parameter estimation methods for failure rate distributions. June(01), 441–445.
2. Barabady, J.. (2005). Reliability and Maintainability Analysis of Crushing Plants in Jajarm Bauxite Mine of Iran. January 2005(01), 109–115. https://doi.org/0-7803-8824-0/05/$20.00 ©2005 IEEE
3. Dolas, D. R., Jaybhaye, M. D., &Deshmukh, S. D.. (2014). Reliability Analysis of Cooling System Water Pump -A Case Study. 3(03).
4. Kumar, V., &Saraswat, S.. (2021). Reliability, Availability, Maintainability & Supportability Analysis of a Boiler. 10(08), 520–525.
5. Dolas, D. R., & Deshmukh, S.. (2015). Reliability Analysis of Cooling System of Diesel Engine. 03(02), 57–61. https://doi.org/10.13189/ujme.2015.030205
6. Quadri, S. A., &Dolas, D. D. R.. (2023). Reliability Analysis Of Complex Repairable Systems: A Roadmap. XVI(06), 33–37.
7. Javad Barabady, Uday Kumar (2008) Reliability analysis of mining equipment: A case study of a crushing plant at Jajarm Bauxite Mine in Iran, Reliability Engineering and System Safety 93 (2008) 647–653
8. S.M. Rezvanizaniani1, J. Barabady2*, M. Valibeigloo1, M. Asghari1, And U. Kumar3 (2009) Reliability Analysis of the Rolling Stock Industry: A Case Study, International Journal of Performability Engineering, Vol. 5, No. 2, January 2009, pp. 167-175.
9. Vivekkumar, Saraswat (2021) Reliability, Availability, Maintainability & Supportability Analysis of a Boiler, Journal of Engineering Research & Technology, Vol. 10 Issue 08, August-2021
10. Masoud Naseri, Javad Barabady (2016) On RAM performance of production facilities operating under the Barents Sea harsh environmental conditions, Int J Syst Assur Eng Manag (July-Sept 2016) 7(3):273–298

Powering the Future: Unveiling The Revolutionary Horizon of Hydrogen Fuel Cell Advancements

Hrishikesh Bhave
✉ hrishikesh.bhave@vpmmpcoe.org

Rahul Kundiya
✉ rahul.kundiya@vpmmpcoe.org

Swanand Joshi
✉ swanand.joshi@vpmmpcoe.org

Deparment of Mechanical Engineering
VPM's Maharshi Parshuram College of Engineering
Velneshwar, Maharashtra

ABSTRACT

The main elements of proton exchange membranes with Traditional PEMs, nanostructured PEMs, and conductive filters are covered in this overview. This thorough overview article covers materials, design improvements, efficiency gains, applications, and obstacles while navigating the complex terrain of recent developments in hydrogen fuel cell technology. In light of growing worldwide environmental concerns, this survey offers an in-depth examination of the present status of research and development on hydrogen fuel cells. Novel polymer blends, nanostructured membranes, and inventive catalysts are just a few examples of the materials that are being explored along with design approaches, efficiency-maximizing technologies, and a variety of uses in transportation, stationary power production, and portable electronics. With a focus on infrastructure, public awareness, and cost, this poll seeks to provide a comprehensive picture of the state of hydrogen fuel cell technology today. This study aims to contribute to the collective knowledge necessary for guiding the paradigm shift towards a sustainable energy future, making it a useful tool for researchers, academics, policymakers, and industry stakeholders.

KEYWORDS *: Hydrogen fuel cell, Renewable energy, Clean energy technology, Proton exchange membrane.*

INTRODUCTION

The need for sustainable energy solutions is growing worldwide, and this has brought hydrogen fuel cell technology to the forefront of the clean energy market [1]. As the globe struggles to cut greenhouse gas emissions and move toward a low-carbon future, hydrogen fuel cells show promise as a flexible and adaptable technology that provides a clean, effective replacement for conventional energy sources. This in-depth analysis seeks to explore the latest developments in hydrogen fuel cell technology, including materials, design breakthroughs, efficiency gains, applications, and the various obstacles preventing its broader use.

With growing environmental concerns and a pressing need to find sustainable alternatives to traditional fossil fuels, [2] this study aims to give a thorough and critical assessment of hydrogen fuel cell technology as it is now. This research tries to clarify the difficulties and prospects in the sector by examining the complex interactions between materials science, engineering advancements, and efficiency optimization. This will help to illuminate the future of hydrogen fuel cell research and development. Examining the latest developments and obstacles in this field is crucial for scholars and researchers, as well as for decision-makers and business partners who are dedicated to advancing the paradigm shift toward a future with more sustainable energy sources

LITERATURE REVIEW

[3] conducted a thorough analysis of the present state and possible applications of hydrogen fuel cell (FC) technology, highlighting the technology's ability to both alleviate the growing energy problem and promote economic expansion. The investigators emphasized the established effectiveness of fuel cells (FCs) as substitute power sources in fixed settings and emphasized their developing function in the transportation and portable domains. The examination of the literature carefully

detailed technological developments, especially in urban transit systems that involve land, sea, air, and rail transportation. The study also provided information on the use of FCs in consumer devices including laptops, cellphones, chargers, and auxiliary power units (APUs), as well as compact power units for military equipment and instructional packages also [4] recognized the significant significance of hydrogen fuel cell vehicle (FCV) technology for both environmental protection and energy security, and they performed a thorough investigation of the state of FCV technology in China. Policy support, market application, and technology readiness level were the three key perspectives that the study looked at. It highlighted the remarkable progress that China has made in the last ten years through governmental policy initiatives as well as the efforts of businesses in the hydrogen and FCV industries. Nonetheless, the researchers found that ongoing financial and technological obstacles prevent FCVs from being widely commercialized. The report focused on the distinct features and critical concerns of every industrial chain sector, stressing the significance of resolving these difficulties to ensure long-term prosperity. Furthermore, [5] examined the difficulties and developments in the creation of hydrogen-fueled buses, with a special emphasis on urban transportation, with a concentration on fuel-cell electric cars. The research carefully examined the advancements and difficulties encountered in the implementation of hydrogen-powered buses, gathering, and evaluating relevant information from energy-related sources. Three key areas of the development of fuel-cell electric buses were examined: production, efficiency, and consumption of energy. In contrast to gasoline, gas, and battery cars, the first element discussed the qualities and advantages of hydrogen supply for electric buses, underscoring the critical need to provide sustainable and climate-neutral public transportation. Assessing the well-to-wheel, tank-to-wheel, delivery, and storage losses of four different engine types—gasoline, diesel, gas, and electric—was done to solve the efficiency problem whereas [6] explored the vital role that heterogeneous electrocatalysis plays in developing carbon-neutral and sustainable pathways for the generation of chemicals and energy. The main topic of discussion was the importance of determining the active centres on the surface of electrocatalysts and the factors that have an impact on them. This is because identifying these centres is essential to improving the overall efficiency of electrochemical devices that operate at the electrode/electrolyte interface. The significance of surface structure, nanoparticle size and shape, and electrolyte composition in influencing catalytic performance was highlighted in the work. Important elements for the identification of active centres were clarified, and the study brought to light issues that the authors believe should be addressed in a similar domain [7] conducted a detailed investigation of the challenges involved in incorporating hydrogen into the energy networks of the Netherlands, identifying hydrogen as a critical medium for mitigating climate change and improving energy security in the shift to sustainable energy. The study used a mixed-methods approach, integrating findings from an extensive examination of the literature, analyses of policy documents, assessments of 59 field initiatives, and in-depth discussions with 33 important stakeholders from various industries. Key stakeholders in the Dutch hydrogen industry were not only identified and categorized by the study, but it also shed light on how they relate to one another and the difficulties that arise during integration. In their examination of the situation of fuel cells in the automotive sector, [8] highlights the necessity of a practical strategy to lower total fuel cell costs and promote integration. By addressing the fundamental issues impeding the adoption of fuel cell electric cars (FCEVs), [9] expand the viewpoint and provide a tactical road map for a smooth transition. The techno-economic performance of various hydrogen shades is thoroughly examined by [10], who offer a sophisticated knowledge of the obstacles and possible solutions for the development of infrastructure and cost effective hydrogen generation. [11] focus on the crucial element of hydrogen storage, highlighting developing approaches for secure, lightweight, and reasonably priced storage devices while hinting at the difficulties associated with low production rates and high commercialization costs. [12] expand on this further by examining the challenges, developments, and prospects for fostering a low-carbon hydrogen economy. They also explore the worldwide context of hydrogen as an alternative energy source and classify its production into different colour spectrums.

MATERIALS ADVANCEMENTS

Proton Exchange Membranes

Proton exchange membranes, or PEMs, are an essential part of hydrogen fuel cell technology that affect the system's overall performance and efficiency [13]. Because of their superior proton conductivity, perfluorosulfonic acid (PFSA) membranes—such as Nafion—have historically been used widely. However, difficulties with water management, limited temperature tolerance, and high cost have prompted research into other PEM materials.Novel polymer blends have emerged as a possible substitute for conventional PFSA membranes in recent breakthroughs. Some of the drawbacks of traditional PEMs have been addressed by blending polymers such as polybenzimidazole (PBI) with sulfonated polymers, which have shown increased thermal stability and cost-effectiveness [14]. Furthermore, incorporating nanomaterials into PEMs—like graphene oxide and carbon nanotubes—has the potential to improve mechanical strength and proton conductivity while mitigating some of the shortcomings of conventional materials. Simultaneously, conductive fillers, including metal nanoparticles or conductive polymers, have surfaced as a means of augmenting PEMs' electrical conductivity to enhance fuel cell efficiency overall across a range of operating scenarios. To increase PEMs' mechanical stability and chemical resistance, cross-linking techniques have been investigated. This has enhanced PEMs' longevity and reduced problems associated with deterioration over time Moreover, the operating temperature range of fuel cells has increased due to developments in high-temperature PEMs, such as hydrocarbon-based and phosphoric acid-doped membranes [15]. This is especially important for applications that need more power density and efficiency. To achieve scalability and affordability, researchers are constantly investigating cost effective alternatives, such as bio-based polymers and new production processes, to solve the financial obstacles associated with existing materials. Going ahead, the path of PEM development involves striking a careful balance between mechanical durability, cost-effectiveness, and proton conductivity. To expedite the commercial viability of hydrogen fuel cells, future research paths should investigate innovative polymer chemistries, enhanced characterization techniques, and scalable production procedures. The development of Proton Exchange Membranes is an important aspect of hydrogen fuel cell technology advancement, providing a means of improving efficiency, robustness, and economic feasibility. Sustaining the shift to sustainable energy sources and maximizing the potential of PEMs will need ongoing multidisciplinary work.

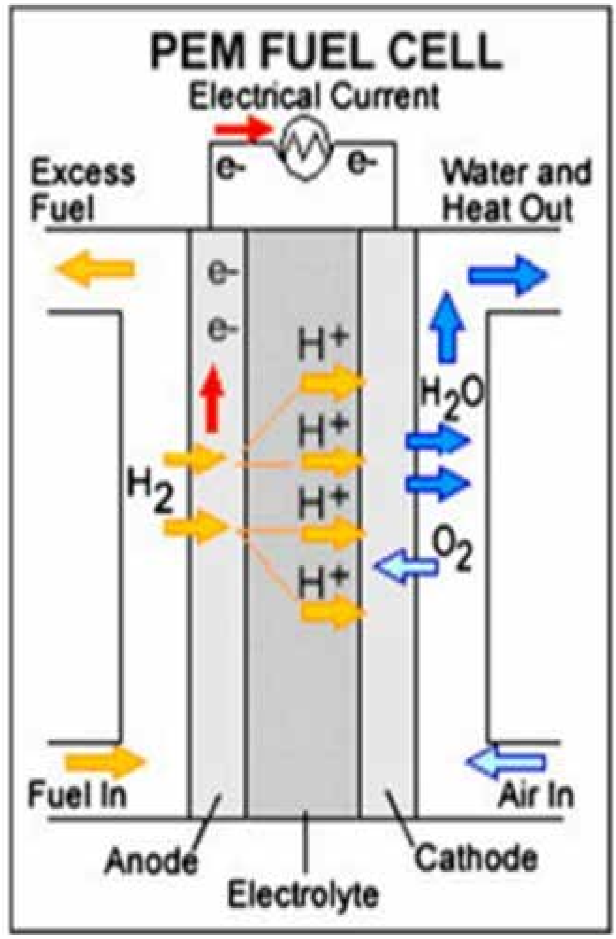

Figure 1. Overview of Polymer electrolyte membrane fuel cell [24]

Traditional PEMs

Traditional PFSA membranes have several disadvantages even though they are good at promoting proton transport [14]. Researchers are looking at other materials due to the high costs of producing PFSA membranes, their limited temperature tolerance, and the difficulties they have managing water. These membranes are widely used, however their suitability for a variety of operating environments and budgetconscious applications is questioned. Acknowledging these drawbacks, new developments in the area have directed research toward exploring unique polymer mixes as possible substitutes for conventional PFSA membranes. Combining sulfonated polymers with polymers, including polybenzimidazole (PBI), has shown promise. This method alleviates some of the issues related to traditional PEMs by improving thermal stability in addition to addressing the membranes' cost-effectiveness. Although proton conductivity has been mostly determined by classic PFSA membranes, continuing research efforts highlight the need for materials that can balance cost, performance, and operational flexibility Finding the perfect proton exchange membrane (PEM) requires careful balancing, and scientists are working to develop creative solutions that can overcome the drawbacks of conventional PEMs and eventually enhance and widely use hydrogen fuel cell technology.

Novel Polymer Blends

In hydrogen fuel cell technology, novel polymer blends have emerged as viable substitutes for proton exchange membranes (PEMs). These blends seek to overcome the drawbacks of conventional PFSA membranes by fusing the beneficial qualities of many polymers. The possibility for increased thermal stability is one of the main benefits; this is important since it guarantees the long-term performance and longevity of PEMs [16]. In addition, the search for new polymer blends aims to improve cost effectiveness, which is an important factor in the general acceptance of hydrogen fuel cell technology.

Scalability and accessibility are made possible in a variety of applications by the possibility of obtaining equivalent or better proton conductivity using more economically feasible materials. Consequently, these mixes aid in the development of PEMs by providing a well-rounded.

Nanostructured PEMs

Materials at the nanoscale, such as carbon nanotubes and graphene oxide, are included into the membrane matrix of nanostructured PEMs [17]. By adding these nanomaterial's, the PEM becomes extremely electrically conductive, which improves the efficiency of proton transport inside the fuel cell. Concerns about the longevity and structural integrity of the membrane are allayed by the increased mechanical strength brought about by the vast surface area and special qualities of nanoparticles. Nanostructured PEMs are useful for more than only improving mechanical and conductivity characteristics [18]. These sophisticated membranes perform better in a range of operational environments and show increased resilience to deterioration. Moreover, the use of nanomaterials creates opportunities for modifying PEM characteristics, enabling scientists to design membranes according to particular application needs. The potential of nanostructured PEMs to get beyond some of the drawbacks of conventional PEMs is what makes them significant. Because of their special qualities, they are especially useful in applications where efficiency, longevity, and flexibility under a range of operating circumstances are critical. Nanostructured PEMs are a potential breakthrough that might usher in a new era of efficiency and dependability in hydrogen fuel cell technology as researchers continue to explore the world of nanomaterials.

Conductive Filters

Proton transport within the PEM is made more efficient using conductive fillers [19]. Electrochemical processes within the fuel cell are facilitated by the effective catalytic activity of metal nanoparticles, such as those made of palladium or platinum. In addition to improving proton conductivity, this catalytic activity raises the hydrogen fuel cell's overall effectiveness and performance. Furthermore, conductive fillers support PEMs' mechanical toughness. By adding these fillers, the membrane's structural integrity is improved and worries about mechanical deterioration with prolonged use are addressed. Because of their enhanced mechanical strength and proton conductivity, conductive fillers are advantageous in the development of PEM technology.

Conductive fillers are more useful than conventional PEM materials since they provide a mechanism to modify the membrane's characteristics for certain uses [20]. Conductive fillers are a flexible tool for enhancing PEMs, and they are playing a critical role in advancing the overall efficiency, durability, and application of hydrogen fuel cell technology as researchers investigate new materials and manufacturing procedures

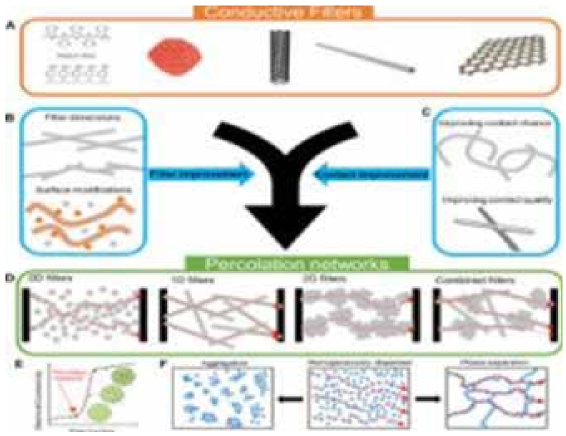

Figure 2: Conductive Filters by [23]

Catalyst Materials

The selection of suitable catalyst materials has a significant impact on the catalytic activity of hydrogen fuel cells [21]. Efficient proton exchange reactions have traditionally been associated with conventional catalysts, frequently utilizing platinum. Recent developments in catalyst materials, however, are meant to solve issues with exorbitant prices, scarce supply, and the requirement for increased durability.

Non-precious metal catalysts, including iron, cobalt, and nickel, are being investigated by researchers to find more environmentally friendly substitutes. These materials aim to preserve or improve the catalytic efficiency necessary for the best fuel cell performance, but they also provide a more economical and ecologically friendly alternative. The incorporation of these substitute catalyst materials is consistent with the overarching objective of increasing the economic feasibility and accessibility of fuel cell technology [22].

Furthermore, nanomaterials have shown promise as catalytic supports, such as graphene and carbon nanotubes. Their large surface area and outstanding conductivity support more effective electrochemical processes inside the fuel cell by facilitating efficient catalyst use. By enhancing durability and performance, the combination of these nanomaterials and catalysts pushes the limits of fuel cell technology.

Electrode Materials

In hydrogen fuel cells, the materials used for the electrodes are essential for promoting electrochemical processes and overall cell performance. One layer of carbon atoms organized in a hexagonal lattice, known as graphene, has gained attention as a potential electrode material [25]. Its superior surface area and electrical conductivity enhance catalytic activity and facilitate effective electrochemical reactions at the electrode interfaces. The incorporation of graphene improves fuel cells' overall durability and performance.

A further source of electrode material innovation is represented by transition metal oxides, such as cobalt and manganese oxide. Excellent electrocatalytic activity and stability characterize these materials, which makes them desirable candidates for fuel cell electrode applications. The goal of transition metal oxide research is to lessen dependency on precious metals while preserving or enhancing performance indicators.

Carbon nanotubes (CNTs) have become more popular as electrode components than conventional materials [26]. Because of their great mechanical strength and electrical conductivity, carbon nanotubes (CNTs) can support catalysts and ease the transport of electrons during electrochemical processes. This invention advances the creation of electrodes that are both lightweight and effective.

Moreover, electrodes with complex shapes have been created using three-dimensional (3D) printing methods, increasing surface area and improving mass movement inside the fuel cell. Electrodes that are 3D printed provide enhanced functionality and customizable options, mitigating the drawbacks of traditional production methods.

EFFICIENCY ENHANCEMENT TECHNOLOGIES

A crucial factor in the development and broad use of hydrogen fuel cell technology is efficiency [27]. More recently, a variety of technologies have been developed to improve fuel cell efficiency overall. These technologies range from sophisticated control algorithms to creative heat management strategies.

Advanced Control Algorithms

Advanced control algorithms have become essential for maximizing hydrogen fuel cell performance [28]. Real-time modifications to operational parameters are made possible by machine learning algorithms and model-based predictive control, which maximize energy production while guaranteeing steady and effective performance. These algorithms help fuel cells respond dynamically, increasing their capacity to adjust to changing load circumstances and enhancing system performance.

Waste Heat Recovery Systems

The recovery and usage of waste heat produced by the electrochemical reactions occurring within fuel cells is one aspect of efficiency improvement efforts. Sophisticated waste heat recovery systems are designed to collect and reuse thermal energy, making the process of energy conversion more efficient and sustainable [29]. The conversion of waste heat into power is made easier by the integration of heat exchangers and thermoelectric materials, which enhances the overall efficiency of hydrogen fuel cells.

Thermal Management Techniques

A crucial component of fuel cell efficiency, thermal management affects both lifetime and performance. The goal of recent advancements in thermal management strategies is to keep different fuel cell components running at their ideal temperatures Active cooling, phase change materials, and sophisticated heat exchangers are some of the strategies that reduce thermal gradients [30], guaranteeing even temperature distribution and halting material deterioration. Good heat control increases the longevity and dependability of hydrogen fuel cells in addition to their efficiency.

The combination of efficiency enhancement methods makes hydrogen fuel cells more feasible and competitive in a range of applications. The combination of cutting-edge thermal management strategies, waste heat recovery systems, and sophisticated control algorithms offers a comprehensive strategy for increasing energy conversion efficiencies, which enhances the appeal of hydrogen fuel cells as a clean and sustainable energy source.

CONCLUSION

Finally, a full analysis of current developments in hydrogen fuel cell technology is provided by this study, with special attention to materials, design breakthroughs, efficiency gains, applications, and difficulties. The rapid evolution of fuel cell components is highlighted by the multidimensional research of novel polymer blends, nanostructured membranes, enhanced catalysts, and revolutionary electrode materials. Hydrogen fuel cells' adaptability is demonstrated by their design techniques, efficiency improvement technologies, and many uses in transportation, stationary power production, and portable electronics. Even with the great advancements, there are still many obstacles to overcome, including those related to cost, infrastructure development, and public awareness. It is clear that hydrogen fuel cells have the ability to completely transform sustainable energy solutions as we work through these obstacles. The efficiency of the technology is further increased by the use of sophisticated control algorithms, waste heat recovery systems, and efficient thermal management strategies. Hydrogen fuel cells are expected to undergo constant improvement in the future, which will need for ongoing multidisciplinary research, legislative backing, and industrial cooperation. By providing insights into the present and potential future of hydrogen fuel cell technology, this study adds to the larger conversation on sustainable energy and encourages coordinated efforts to realise a future that is more energy-efficient and ecologically sustainable.

REFERENCES

1. Staffell, I., Scamman, D., Abad, A.V., Balcombe, P., Dodds, P.E., Ekins, P., Shah, N. and Ward, K.R., 2019. The role of hydrogen and fuel cells in the global energy system. Energy & Environmental Science, 12(2), pp.463-491.
2. Ebhota, W.S. and Jen, T.C., 2020. Fossil fuels environmental challenges and the role of solar photovoltaic technology advances in fast tracking hybrid renewable energy system. International Journal of Precision Engineering and Manufacturing-Green Technology, 7, pp.97-117.
3. Rath, R., Kumar, P., Mohanty, S. and Nayak, S.K., 2019. Recent advances, unsolved deficiencies, and future perspectives of hydrogen fuel cells in transportation and portable sectors. International Journal of Energy Research, 43(15), pp.8931-8955.
4. Zhao, F., Mu, Z., Hao, H., Liu, Z., He, X., Victor Przesmitzki, S. and Ahmad Amer, A., 2020. Hydrogen

fuel cell vehicle development in China: An industry chain perspective. Energy Technology, 8(11), p.2000179.

5. Vodovozov, V., Raud, Z. and Petlenkov, E., 2022. Review of Energy Challenges and Horizons of Hydrogen City Buses. Energies, 15(19), p.6945.

6. Garlyyev, B., Fichtner, J., Piqué, O., Schneider, O., Bandarenka, A.S. and Calle-Vallejo, F., 2019. Revealing the nature of active sites in electrocatalysis. Chemical Science, 10(35), pp.8060-8075.

7. Hasankhani, M., van Engelen, J., Celik, S. and Diehl, J.C., 2024. Unveiling complexity of hydrogen integration: A multi-faceted exploration of challenges in the Dutch context. Journal of Cleaner Production, 434, p.139927.

8. Olabi, A.G., Wilberforce, T. and Abdelkareem, M.A., 2021. Fuel cell application in the automotive industry and future perspective. Energy, 214, p.118955.

9. Saritas, O., Meissner, D. and Sokolov, A., 2019. A transition management roadmap for fuel cell electric vehicles (FCEVs). Journal of the Knowledge Economy, 10, pp.1183-1203.

10. Mohideen, M.M., Subramanian, B., Sun, J., Ge, J., Guo, H., Radhamani, A.V., Ramakrishna, S. and Liu, Y., 2023. Techno-economic analysis of different shades of renewable and non renewable energy-based hydrogen for fuel cell electric vehicles. Renewable and Sustainable Energy Reviews, 174, p.113153.

11. Alves, M.P., Gul, W., Cimini Junior, C.A. and Ha, S.K., 2022. A review on industrial perspectives and challenges on material, manufacturing, design and development of compressed hydrogen storage tanks for the transportation sector. Energies, 15(14), p.5152.

12. Qureshi, F., Yusuf, M., Kamyab, H., Vo, D.V.N., Chelliapan, S., Joo, S.W. and Vasseghian, Y., 2022. Latest eco-friendly avenues on hydrogen production towards a circular bioeconomy: Currents challenges, innovative insights, and future perspectives. Renewable and Sustainable Energy Reviews, 168, p.112916.

13. Wu, D., Peng, C., Yin, C. and Tang, H., 2020. Review of system integration and control of proton exchange membrane fuel cells. Electrochemical Energy Reviews, 3, pp.466-505.

14. Maiti, T.K., Singh, J., Majhi, J., Ahuja, A., Maiti, S., Dixit, P., Bhushan, S., Bandyopadhyay, A. and Chattopadhyay, S., 2022. Advances in polybenzimidazole based membranes for fuel cell applications that overcome Nafion membranes constraints. Polymer, p.125151.

15. Nimir, W., Al-Othman, A., Tawalbeh, M., Al Makky, A., Ali, A., Karimi-Maleh, H., Karimi, F. and Karaman, C., 2023. Approaches towards the development of heteropolyacid-based high temperature membranes for PEM fuel cells. International Journal of Hydrogen Energy, 48(17), pp.6638-6656.

16. Wirkert, F.J., Roth, J., Jagalski, S., Neuhaus, P., Rost, U. and Brodmann, M., 2020. A modular design approach for PEM electrolyser systems with homogeneous operation conditions and highly efficient heat management. International Journal of Hydrogen Energy, 45(2), pp.1226- 1235.

17. Farooqui, U.R., Ahmad, A.L. and Hamid, N.A., 2018. Graphene oxide: A promising membrane material for fuel cells. Renewable and Sustainable Energy Reviews, 82, pp.714- 733.

18. Zeng, M., Liu, W., Guo, H., Li, T., Li, Q., Zhao, C., Li, X. and Li, H., 2022. Polyoxometalate Cross-Linked Proton Exchange Membranes with Post-Assembled Nanostructures for High Temperature Proton Conduction. ACS Applied Energy Materials, 5(7), pp.9058-9069.

19. Karimi, M.B., Hooshyari, K., Salarizadeh, P., Beydaghi, H., Ortiz-Martínez, V.M., Ortiz, A., Uribe, I.O. and Mohammadi, F., 2021. A comprehensive review on the proton conductivity of proton exchange membranes (PEMs) under anhydrous conditions: Proton conductivity upper bound. International Journal of Hydrogen Energy, 46(69), pp.34413-34437.

20. Sun, X., Simonsen, S.C., Norby, T. and Chatzitakis, A., 2019. Composite membranes for high temperature PEM fuel cells and electrolysers: a critical review. Membranes, 9(7), p.83.

21. Samad, S., Loh, K.S., Wong, W.Y., Lee, T.K., Sunarso, J., Chong, S.T. and Daud, W.R.W., 2018. Carbon and non-carbon support materials for platinum-based catalysts in fuel cells. international journal of hydrogen energy, 43(16), pp.7823-7854.

22. Vilela, C., Silvestre, A.J., Figueiredo, F.M. and Freire, C.S., 2019. Nanocellulose-based materials as components of polymer electrolyte fuel cells. Journal of Materials Chemistry A, 7(35), pp.20045-20074.

23. Cho, K.W., Sunwoo, S.H., Hong, Y.J., Koo, J.H., Kim, J.H., Baik, S., Hyeon, T. and Kim, D.H., 2021.

Soft bioelectronics based on nanomaterials. Chemical Reviews, 122(5), pp.5068- 5143.

24. Wang, Y.; Chen, K.S.; Mishler, J.; Cho, S.C.; Adroher, X.C. A review of polymer electrolyte membrane fuel cells: Technology, applications, and needs on fundamental research. Appl. Energy 2011, 88, 981–1007

25. Salahdin, O.D., Sayadi, H., Solanki, R., Parra, R.M.R., Al-Thamir, M., Jalil, A.T., Izzat, S.E., Hammid, A.T., Arenas, L.A.B. and Kianfar, E., 2022. Graphene and carbon structures and nanomaterials for energy storage. Applied Physics A, 128(8), p.703.

26. Kumar, S., Nehra, M., Kedia, D., Dilbaghi, N., Tankeshwar, K. and Kim, K.H., 2018. Carbon nanotubes: A potential material for energy conversion and storage. Progress in energy and combustion science, 64, pp.219-253.

27. Fan, L., Tu, Z. and Chan, S.H., 2021. Recent development of hydrogen and fuel cell technologies: A review. Energy Reports, 7, pp.8421-8446.

28. Yang, B., Li, J., Li, Y., Guo, Z., Zeng, K., Shu, H., Cao, P. and Ren, Y., 2022. A critical survey of proton exchange membrane fuel cell system control: Summaries, advances, and perspectives. International Journal of Hydrogen Energy, 47(17), pp.9986-10020.

29. Jouhara, H., Khordehgah, N., Almahmoud, S., Delpech, B., Chauhan, A. and Tassou, S.A., 2018. Waste heat recovery technologies and applications. Thermal Science and Engineering Progress, 6, pp.268-289.

30. Yuan, K., Shi, J., Aftab, W., Qin, M., Usman, A., Zhou, F., Lv, Y., Gao, S. and Zou, R., 2020. Engineering the thermal conductivity of functional phase-change materials for heat energy conversion, storage, and utilization. Advanced Functional Materials, 30(8), p.1904228.

Review on Micro-channels Manufacturing Methods and Associated Challenges

Pranav U. Sawant
Department of Mechanical Engineering
Maharshi Parshuram College of Engineering
Velneshwar, Maharashtra
✉ pranav.sawant@vpmmpcoe.org

Rahul R. Kundiya
Department of Mechanical Engineering
Maharshi Parshuram College of Engineering
Velneshwar, Maharashtra
✉ rahul.kundiya@vpmmpcoe.org

ABSTRACT

The review conducted in this paper focusses on study of various manufacturing methods of Microfluidic channels. Each of these methods exhibit certain challenges in manufacturing of micro channels of certain materials. Common challenges being formation of burrs on micro channels. This paper describes all such challenge in manufacturing of micro channels. Some sections of this paper collectively compare different manufacturing methods of micro channels using the same material; some sections describe relative advantages of using one method over the others. Most prominent methods of micro channel manufacturing like Lithography, Wire Electro-discharge machining, Micro milling, Cryogenic machining have been discussed along with their manufacturing challenges in this presented work. Some of the solutions to challenges have also been presented in this review work.

KEYWORDS *: PDMS, WEDM, LIMM, AWJ.*

INTRODUCTION

Microfluidic devices represent a crucial technological advancement in the field of fluid mechanics, enabling precise manipulation and control of fluids at the micro scale level. These devices, also known as lab-on-a-chip systems, have revolutionized various fields including biotechnology, medicine, chemistry, and engineering. Microfluidic devices have emerged as powerful tools in various fields such as biomedical engineering, chemistry, and physics due to their ability to manipulate fluids at the micro scale level. These tools provide accurate control over fluid flow, opening up a variety of uses for chemical synthesis, medication delivery, and diagnostics, among others. The growing demand for microfluidic devices has led to an increasing need for scalable and efficient manufacturing techniques. The present review aims to give a thorough overview of the several methods of manufacturing used in the development of microfluidic devices. From traditional techniques such as soft lithography to advanced additive manufacturing processes like 3D printing, each method offers unique advantages and challenges that influence their suitability for specific applications. The present article attempts to be a useful tool for microfluidics researchers, engineers, and practitioners by combining the most recent technical advancements and research discoveries. It will facilitate the design and construction of contemporary microfluidic devices with improved functionality and performance by revealing areas for future study and development and offering information about the most recent manufacturing techniques currently in use. Microfluidic devices can be fabricated using various techniques such as soft lithography, micro-machining, and 3D printing. These methods allow for the creation of intricate micro channels, valves, pumps, and sensors on a chip substrate. Despite their immense potential, microfluidic devices also face challenges such as optimization of fluid handling protocols, integration of complex functionalities, standardization of fabrication techniques, and scalability for mass production. Microfluidic devices also face major challenge of manufacturing of Micro-channels.

Burr formation is common problem prominently seen in manufacturing of Microfluidic devices. Specifically, the review focuses on assessing the manufacturing procedures for microfluidic devices in order to identify and assess the issues that arise during the manufacturing of microfluidic channels as well as to describe and evaluate their performance in micro-channel prototyping. Following are some of the methods of manufacturing of Micro fluidic devices:

Lithography: Lithography, typically employed in micro-scale systems and integrated circuits, achieves precise tolerances and smooth surfaces. It involves transferring patterns onto photosensitive material using radiation, such as UV light, in a sterile, dust-free laboratory environment. The following is a description of the prototyping process: Initially, silicon is utilized in the prototyping process as a wafer that functions as a mask. An insignificant amount of polymer and a curing agent are combined prior to the mask's completion. After being placed into the silicon mold, the polymeric mixture solidifies to form the stamp's shape. The following supplies are utilized in the wafer coating process: The trademark AZ 4620 refers to a photo-resist matter that is used to cover the silicon mask, while Hexamethyldisilazane, or HDMS, stimulates the resin to adhere to the oxide on the wafer surface. The curing process is either accelerated or regulated by a curing agent. [1].

Micro-End Milling: Machining methods tailored for miniature components, such as Micro-Turning, Micro-End Milling, and Micro-Drilling, are increasingly favored for producing intricate features in various domains like electronics, biochemistry, and total analysis. Despite their capacity to attain high-quality standards, their utilization in microfluidic devices remains notably scarce, as per findings from the literature review. It was performed on a CNC Machining Center with the following steps: i)Geometry design, ii)Material selection, iii)Prototyping using CNC programming [1]. In their research work; they selected Geometry based on Hosakawa's research work; selected material as Acrylic; they used HSS as a tool for machining.

Electro- Discharge Machining/Sandblasting: Utilizing a combined approach of Wire Electro-Discharge Machining (WEDM) and Sandblasting presents a promising method for evaluating the manufacturing capabilities of small geometric features in prototypes. In experimental context, a stainless steel stencil is crafted using an ONA WEDM AE400 machine. Subsequently, the Sandblasting process complements channel printing on a copper sample. The stencil facilitates the transfer of the design onto the copper sample via a Sandblasting machine, originally designed for high-pressure cleaning of tough surfaces using solid sand particles. The Sandblasting machine exerts an outlet pressure load of 408 Kg, employing silica sand 90/10 as the abrasive material with particle sizes measuring 0.149 mm [1].

Abrasive Water-Jet Technology: The Abrasive Water Jet (AWJ) process, categorized as a non-traditional machining method, is gaining recognition for its proficiency in handling rigid materials, intricate 2D components, and stringent accuracy criteria. For the prototyping phase, an IFB (Integrated Flying Bridge) DWT (Dynamic Water Technology) machine is employed. In the research work; the trajectory design adopted a serpentine channel configuration, facilitated by proprietary 2D Flowpath FLOW'S software for machine control. To regulate the micro-channel depth while minimizing material removal rates, a specialized abrasive, HPA #100, was utilized. Calculations are made for initial parameters including pressure, nozzle tip distance, velocity, and material thickness. It was discovered after calibration that a micro-channel depth of at least 0.1524 mm could be reached. These outcomes were achieved utilizing the subsequent configurations: a water pressure of 107,484 kilopascals (KPa), a nozzle elevation of 3.81 millimeters (mm), a speed of 1143 millimeters per minute (mm/min), and a material thickness of 0.762 mm. [1].

Polydimethylsilloxane casting: The most common way to prototype fluidic layers in academic research involves pouring a liquid called polydimethylsiloxane (PDMS) onto a mold. When the PDMS cures, it forms a clear rubbery material that can be taken off the mold, leaving behind the micro features. This method is affordable and can produce devices with very precise features using photolithography techniques to make the mold. PDMS was heavily used in early microfluidic research, making it popular in the industry. However, it has drawbacks like letting gas pass through easily and absorbing small molecules. Additionally, it's not easy to scale up production using this method.

Micro Injection Moulding: Microinjection molding is the most widely adopted and successful process for producing accurate microfluidic features at high volumes. The incredibly low cycle times, functional thermoplastic materials and high part-to-part accuracy makes it a desirable process to create features in microfluidic products. The main drawback of microinjection molding is that the mold tooling can easily cost more than $50,000 and take a few months for fabrication and process optimization. It's a wonderful technique for high volume production, but it's critical to make sure that a design is functional before scaling up to the injection molding process.

Applications for microfluidic devices have grown recently, and they are now a vital component of many life science businesses, including those involved in drug discovery in the pharmaceutical industry, clinical diagnostics, medicine, ecology, and agro-food. The main role involves managing tiny volumes of liquids within a system that has been miniaturized. The primary geometric component of microfluidic systems, the micro channel serves to release and transport fluid. In addition to having features with channels that are microns in size, microfluidics has a more complex architecture than microelectronics. The same systems and capabilities needed for large-scale fluidic handling such as mixers, pumps, valves, filters, and separators [2]. As a result, surface quality and feature accuracy are significant and directly impact functional performance, such as liquid flow rate. The most promising structural materials for microfluidic chips are polymers because of their low cost e.g., disposable after usage, variety in terms of optical and biocompatibility qualities, simplicity of sealing, and suitability for mass replication and rapid prototyping. One manufacturing technology that makes it possible to create complicated geometric features is micro mechanical milling, which is used to fabricate microscopic devices (micro feature sizes) from many types of material. This technique is a straightforward way to use polymer materials to create complex microfluidic device designs. Its benefits over other methods such as chemical processing, energy beam, or silicon etching are that it can create real three-dimensional features and has fewer restrictions on the materials of the workpiece. Moreover, because of its quicker production time and cheaper cost per unit, it is particularly well-suited for prototyping microfluidic devices. Micro milling provides more control over surface polish and higher geometric shape diversity than other processes now in use, such lithography. Micro mechanical machining can result in burr formation and poor surface finish because polymers are ductile.

The primary factor affecting the minimum chip thickness while machining PMMA is the depth of cut, which is followed by feed rate and spindle speed. A significant component of deciding the machined surface and dimensional quality is the machining conditions and approaches employed. Furthermore, the diameters, radius, and geometry of the cutting tool can restrict the sizes of the micro channels and the inside radius of the features.

LITERATURE REVIEW

The development of innovative manufacturing techniques capable of conforming to miniature geometric features has been encouraged by the need for constructing micro size systems for application in engineering, medicine, robotics, and informatics. In the particular instance of microfluidic devices, their uses are becoming more prevalent these days in fields such as biotechnology and medicine for the transportation of DNA, the separation of molecules, or the installation of drug delivery systems. The micro-channels, which are the primary geometric elements that make up micro fluidic devices, are mainly accountable for the discharge and movement of fluids [3]. The relationship between chip load and cutting edge radius in micromachining has been linked to burr generation [4]. Cutting soft materials, such as polymers, can easily produce burrs, which are undesirable for microfluidic devices because they can leak fluidic samples, clog microchannels, and result in catastrophic flow turbulence [5]. In micromachining, the minimum chip thickness is a crucial sign of the production of chips due to the size comparison between the cutting edge radius and the uncut chip thickness. This thin chip thickness has an impact on tool breakage, surface polish, and tool life.

Koji Mishima and his team conducted research on a new method called Pre-Deformation-Assisted Cryogenic Micromachining to make special three-dimensional micro channels. Polydimethylsiloxane (PDMS) is hard to cut using normal methods because it's not stretchy and sticks together a lot. They suggested using a method that involves freezing PDMS with liquid nitrogen to make the cutting easier and faster. They did experiments to understand how this freezing method works for cutting, and they also tried a technique called Pre-Deformation-Assisted Cryogenic Micromachining (PDCM) to make even more unique channel shapes. Their tests showed that they could cut precise and complex 3D micro channels quickly using PDMS [6]. Finally, he stated in his work that below the glass transition temperature of 150K, cutting ability improves, high adhesion vanishes, and PDMS stiffness increases substantially. An effective method for creating both micro holes and micro grooves is cryogenic micromachining employing a micro end mill. By using the PDCM approach, it is simple to create new channels like bent holes that are challenging to create using traditional methods.

Matsumara T. et. al conducted research on Machining System for Micro Fabrication on Glass. In his research work; he highlighted manufacturing difficulties involved in Polydimethylsiloxane (PDMS) substrate. Due to the elastic and sticky material's room temperature instability, PDMS is challenging to machine precisely. One of the two methods listed below is typically used in order to allow machining soft polymer. The first is the high-velocity cutting method. The process with cooling assistance is the other. Both approaches have their foundations on increasing apparent stiffness. However, because the tool radius is too small to achieve high cutting speed, it is challenging to utilize the high speed cutting technique in micro milling and drilling. Soft polymer micro milling and drilling can be done throughout the cooling process. The glass transition temperature (Tg) of soft polymer materials is reliant upon the primary chain configuration of the polymer. The polymer transitions from a rubbery to a glassy state just below Tg, which causes a notable increase in stiffness. Additionally, it is anticipated that the suppression of molecular mobility will result in the disappearance of polymer stickiness. PDMS has a glass transition temperature of 150K, which is lower than that of any other polymer [7].

Shoji M. and Hasegawa T. conducted research on Three-Dimensional Micro structuring of PDMS inside a Micro channel for Functional Microfluidics Devices. In their research work; they performed several experiments to identify nature of PDMS. They studied adhesion properties of PDMS over a range of temperatures. They verified that the suppression of molecular mobility results in the disappearance of polymer adherence [8].

Kakinuma Y. et. al. conducted their experiments on Micromachining of Soft Polymeric Material by applying Cryogenic Cooling. They performed experiments on soft polymers at a temperature of -127 0 C. They examined the possibility of mechanical micromachining of soft polymers. They noticed that the cutting of a microchannel is made possible by the soft polymer's transition from a pure ductile phase to a brittle phase. They came to the conclusion that decreased cutting forces are a direct outcome of a significant reduction in tool wear caused by cryogenic cooling. A cushion of nitrogen is formed between the chip-tool interface when the liquid nitrogen evaporates. During machining, this effect diminishes the cutting force. Less material adheres to the tool due to decreased friction and cutting temperature improves the quality [9].

Yokota K. in his paper on "An Introduction to Polymer materials" explained all the theory regarding polymeric materials at micro level. His research helped us to analyze and understand adhesion properties of polymeric materials [10].

Partha Mallick et. al. conducted review on cryogenic assisted micro-machining of soft polymer. According to them, Mechanical micro-machining techniques offer precise control over geometry, shape versatility, and highly finished surfaces, making them promising for micro-machining soft polymers. However, due to the lack of resistance in these materials at room temperature, cryogenic assistance becomes necessary for proper shearing during mechanical micro-machining. Despite the potential benefits, the adoption of mechanical micro-machining for soft polymers has not been fully established, with only a few researchers worldwide sporadically employing the process. The purpose of this study is to present a concise overview of cryogenic-assisted mechanical micro-machining, with a focus on how successful micro-feature production in soft polymers depends on the integration of mechanical micro-machining principles and controllable aspects of cryogenic technology. The benefits of cryogenic conditions, obstacles in mechanical micro-machining techniques, and advanced developments in cryogenic technology and their prospective application in soft polymer machining have all been reviewed. A detailed discussion is held regarding the physics of soft polymer behavior near the glass transition temperature (Tg) during cryogenic cooling. They also covered how cryogenic machining affects polymer process performance parameters when compared to dry conditions and gave a thorough evaluation of sustainability in soft material cryogenic machining from an economic, social, and environmental standpoint. They compared cryogenic machining with other micro fabrication processes, such as micro-molding, and embossing [11].

Kushendarsyah Saptaji et. al. conducted research on Micromilling of Microfluidic channels using Tapered tool. The micro-milling method is frequently used in the production of molds with micro-sized features, which are essential for numerous applications, such as hot embossing. Burrs during micro-milling, however, provide a considerable barrier, particularly when their sizes are similar to the dimensions of the micro-milled feature. In order to reduce the development of top/side and exit burrs, this study examined the usage of micro-milling tools with tapered geometry. Micro-milling tools of different angles, both tapered and straight, are used, and the burrs that are produced are inspected. An aluminum alloy was used in micro-milling tests to provide common favorable features found in molds for the production of polymer microfluidic devices. The results showed that the increase in taper angle is responsible for the decrease in burrs. In particular, the tapered tool leaves walls that are inclined, which helps to reduce exit burrs that are created during final face milling. It also greatly reduces top burrs. Additionally, embossing tests with the micro-milled tapered geometry molds show better results, which are ascribed to the taper's ability to aid in mold release as well as the decrease in burrs. This study highlights the effectiveness of using tapered shape micro-milling tools to reduce burrs and improve performance in micro-milling applications, especially mold creation in the manufacturing of microfluidic devices. Significant variations in the top/side burr generation were seen in slot milling experiments carried out in both the down and up milling directions. Slot milling is shown to produce significantly more severe top burrs in the down milling direction. As shown in Figure 2, this was seen to be the case for both the tapered and straight milling tools. Regarding the surface finish appearance of the side walls, this was not the case. Regardless of whether the tool was tapered or straight, SEM micrographs showed that Compared to up milling, the side wall finish was substantially better during down milling [12]. Various milling tools used for experimentation can be seen in figure 3. Following figure 1 shows clearly the effect of using tapered tool in reducing burr formation.

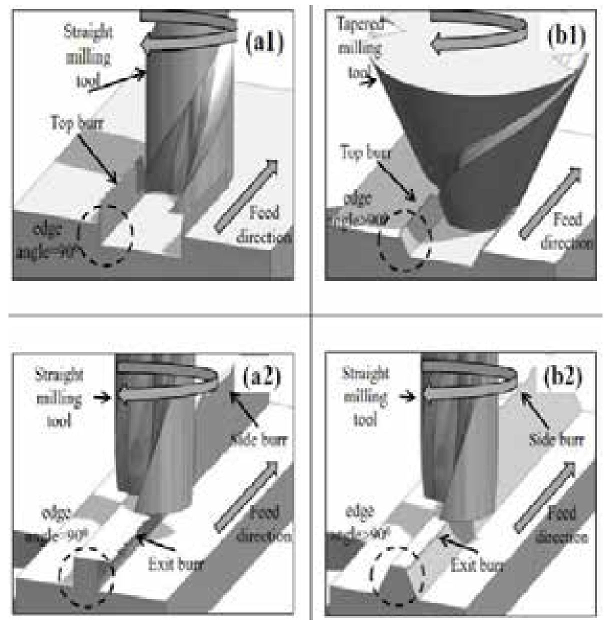

Fig. 1: a1)Slot micromilling with straight tool, a2)Finish face milling with straight tool, b1)Slot milling with tapered tool, b2)Finish face milling with tapered tool [12]

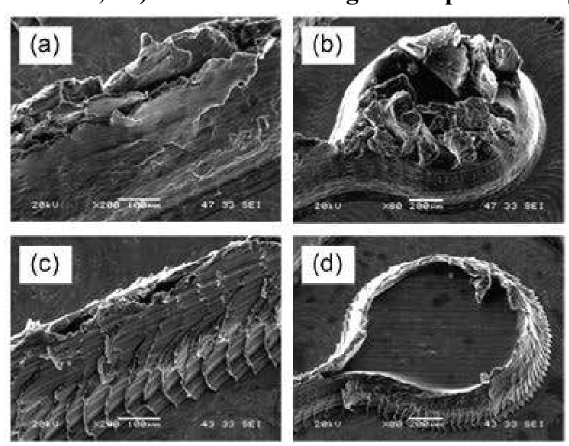

Fig. 2: Scanning electron microscope results of burrs formed by (a)Down milling with straight tool and (b) Down milling with 150 tapered tool, (c) Up miling with straight tool & (d)Up milling with150 tapered tool [12]

Fig.3: Micro-milling tools(from left to right): straight tool, 150, 300, 400 and 500 tapered tools. [12]

K. Saptaji et. al conducted research on “Effect of side edge angle and effective rake angle on top burrs in micro-milling”. In micro-milling, burrs can grow to the same size as the features being generated, which is a common problem. Two main types of burrs occur: exit burrs along the machined surface edge and top/side burrs on the workpiece’s surface. To address burrs, two approaches are commonly used: deburring after machining or reducing burr formation during the process. Deburring micro-scale features is challenging and must be done carefully to avoid damaging the features. Erroneous deburring methods or settings may result in residual stresses, dimensional inaccuracies, damage, and inadequate surface polish. Several machining techniques have been investigated by researchers to lessen burr formation. Using short edge radii, sharp single crystal diamond cutting tools is one efficient technique. However, these tools are costly and require precise machine tooling and vibration control for optimal performance. Another approach involves strengthening the machined wall’s edge using tapered milling tools, which has been reported to reduce burr formation [13].

Ghany, K. A. and his team conducted research on Cutting of 1.2mm thick austenitic stainless steel sheet using pulsed and Nd:YAG laser using a technique called Laser Induced Micro-machining (LIMM). LIMM employs a powerful laser beam focused on the material to remove material through ablation. Compared to traditional mechanical micro-machining, LIMM offers better efficiency in creating accurate geometries, removing debris, and achieving smoother surfaces. This is because the laser can be precisely focused, removing material only from the targeted area. In their study, they used the second harmonic of a high-power Q-switched Nd:YAG laser(Neodymium-doped yttrium aluminum garnet Laser) to create micro-channels with a width of 150 μm on mild steel. They conducted experiments varying the scan speed while keeping the laser energy constant. The results showed promising dimensional accuracy and shape of the generated channels. These findings suggest the potential for manufacturing micro-gratings on mild steel, which could be important components in microfluidic applications [14]. Micro channels upto a width of 100 μm with a depth of 5.94 μm has been successfully fabricated in this present work. Decreasing in width of the micro channel with increase in scanning speed as observed in this work is in agreement with the available literatures.

Kevin V. Christ et. al. conducted research on Micro End Milling of Polystyrene for Microfluidic Applications. Thermoplastic microfluidics can currently be prototyped using laser ablation, stereolithography, and micro end milling. Laser ablation is a fast and accurate method of material removal by the use of laser pulses; nevertheless, it changes the ablated region’s composition and has issues producing channels with rectangular cross sections. Stereolithography is a rather slow process with limited material alternatives that uses lasers to polymerize pieces of liquid resin. Using small end mills, micro end milling can produce three-dimensional, high aspect ratio microscale features and remove material similarly to macro-scale milling. This process has been demonstrated lately for microchannels in PMMA thermoplastics and has proven successful in creating precision parts in metals. Polydimethylsiloxane (PDMS) is a common material used in research labs to produce microfluidic devices since lithography and molding are well-established procedures. Nonetheless, thermoplastics are frequently employed for mass-produced polymer microfluidic devices due to their superior characteristics in numerous applications. Thus, there is a great need in research labs for methods to rapidly develop thermoplastic devices. They created microfluidic devices out of polystyrene using micro end milling. They looked into how burrs along channel edges, bottom surface roughness, and channel width were affected by tool speed, feed rate, and depth of cut. They discovered that the optimal channels are obtained with low cutting depths and high feed rates. Several noteworthy aspects of the production process are revealed by microscope photographs of a milled micro channel in polystyrene. In comparison with the top surfaces of the polystyrene substrates, the channel bottoms are noticeably rougher. Secondly, there are differences in the channel width between the tool diameter and the required size. Finally, burrs are seen along the borders of the channels. Although these characteristics are part and parcel of the process, they can be reduced by carefully choosing the process factors. The dependence of burring, surface roughness, and channel dimensional error on feed rate, depth of cut, and tool rotation speed was demonstrated by surface reaction experiments. The dimensional inaccuracy varies between 10 and 20 µm for different parameter combinations. Exact measurements reveal minimal spindle runout, with a 10 µm baseline runout because of collet eccentricity. The contour plot's lack of insensitive regions emphasizes how crucial it is to precisely modify process factors in order to achieve the best outcomes [15].

Research on micromilling of polymer materials for microfluidic applications was done by Ampara Aramcharoen et al. One practical method for creating microfluidic devices is micro mechanical milling, which can be used to efficiently and economically build complicated geometries. In particular, cutting techniques for micromilling of Polycarbonate (PC) and polymethyl methacrylate (PMMA) materials for microfluidic chip applications were described in this study. The suggested approaches demonstrated how well biocompatible polymer materials can be used to create microfluidic chips with complex micro channel and micro pillar array features using micro milling. Notably, the procedure may produce high aspect ratios of up to three and produces machined surfaces of excellent quality. Research on Polycarbonate and Polymethyl methacrylate materials focused on micro mechanical milling for polymer microfluidic applications. PC produces more burrs than polymethyl methacrylate because it is more ductile, particularly at deeper cuts. Size and aspect ratio of microchannels are limited by tool geometry. For intricate designs, smaller tools work well, but they also need more time to machine and are more brittle [16].

CONCLUSION:

Following point have been concluded from the Review work:

1) Burr formation is common problem arises when microchannels are cut using micromilling method. When Micro channels are manufactured by Micromilling method using micromilling tools on Aluminium alloy then, burr formation keeps on reducing with increase of taper angle of micro-milling tool. Both top & Exit burrs formed can be reduced by selecting more tapered milling tool instead of straight milling tool.
2) It has been observed that top burrs are significantly more severe during slot milling in the downward direction.
3) While down milling produces more top burrs than up milling, it produces a smoother side wall surface.
4) Higher tapered tool angles produce a bigger machined edge angle, which can aid in further minimizing exit burrs produced during the subsequent finishing face milling procedure.
5) On traditional machining centers, tapered micromilling tools can be used to create molds with burr-free micro-features for embossing molds. Trials of hot embossing with a tapered mold design demonstrated good process performance, particularly in the de-embossing phase.
6) Below the glass transition temperature of 150K, PDMS's cutting performance improves, its high adhesion vanishes, and its stiffness increases noticeably.
7) A good method for creating both micro holes and micro grooves is cryogenic micromachining with a micro end mill.
8) Compared to the typical Lithography process, the Micro-End Milling procedure can be employed in prototyping to create micro-channels with the proper geometry and surface finishing.
9) Microchannel cutting is less likely to be

accomplished with hard materials. On the other hand, hard materials with a reasonably excellent surface polish can have microchannels cut out of them using abrasive water jet technology.

10) Compared to other existing micro-mechanical techniques, the Micro-End Milling procedure can produce the original design's shape with the fewest topographical errors.

11) Laser-induced micromachining is more efficient than mechanical micromachining when it comes to precise work or feature geometry, effective debris removal, and improved surface morphology.

12) For thermoplastic materials, it was discovered that the optimal channels are produced by low cutting depths and high feed rates.

13) When it comes to better surface morphology, efficient debris removal, and precise work or feature geometry, laser-induced micromachining outperforms mechanical micromachining.

14) Materials made of polycarbonates and polymethylmethacrylate were used in the experiments. Using a low depth of cut and low feed rate could improve the surface finish.

REFERENCES

1. Ana Laura Jauregui, Hector R. Siller, Giro A. Rodriguez, Alex Elias-Ziiftiga, "Evaluation of Manufacturing Processes for Microfluidic Devices", CPl 181, Third Manufacturing Engineering Society International Conference, American Institute of Physics 978-0-7354-0722-0/09

2. Becker, H. and Gartner C. , "Polymer micro fabrication methods for microfluidic analytical applications", Electrophoresis, Vol. 21, pp.12–26 (2000)

3. T. Masuzawa and H. K. Tonshoff, "Three-Dimensional Micromachining by Machine Tools", CIRP Annals 46, 621-628 (1997)

4. Aramcharoen, A. and Mativenga, P.T. "Size effect and tool geometry in micromilling of tool". (2009)

5. Hira, S.I. and Yoshioka, M. 'Micro-cutting of polytetrafluoroetylene (PTFE) for application of micro-fluidic devices', Key Engineering Materials, Vol. 329, pp.577–582, (2007)

6. Koji Mishima, Yasuhiro Kakinuma and Tojiro Aoyama, "Journal of Advanced Mechanical Design, Systems, and Manufacturing" Vol. 4, No. 5, 2010

7. Matsumura T., 2004, "Machining System for Micro Fabrication on Glass", Proc. of 2004 JUSFA, pp.1-6.

8. Shoji M. and Hasegawa T., 2006, Three-Dimensional Microstructuring of PDMS inside a Microchannel for Functional Microfluidics Devices, TAS2006, pp.669-671.

9. Kakinuma Y., Yasuda N. and Aoyama T., 2008, Micromachining of Soft Polymer Material applying Cryogenic Cooling J. of Adv. Mech. Des. Syst. and Manuf., Vol.2, pp.560-569.

10. Yokota K., "An Introduction to Polymer materials",1999, KAGAKU-DOJIN PUBLISHING CO. pp.95-101, 143-161.

11. Partha Sarathi Mallick, Ashwani Pratap, Karali Patra, "Review on cryogenic assisted micro-machining of soft polymer: An emphasis on molecular physics, chamber design, performance analysis and sustainability", Journal of Manufacturing Processes, Volume 80, Pages 930-957

12. Kushendarsyah Saptaji, Sathyan Subbiah, "Burr Reduction of Micro-milled Microfluidic Channels Mould Using a Tapered Tool", Advances in Material & Processing Technologies Conference, Procedia Engineering 184 (2017) 137 – 144.

13. K. Saptaji, S. Subbiah, and J. S. Dhupia, "Effect of side edge angle and effective rake angle on top burrs in micro-milling", Precision Engineering, vol. 36, no. 3, pp. 444–450, Jul. 2012

14. Ghany, K. A. and Newishy, M. (2005), "Cutting of 1.2mm thick austenitic stainless steel sheet using pulsed and CW Nd:YAG laser", Journal of Materials Processing Technology, Vol. 168, pp. 438-447

15. Kevin V. Christ, Bryce B. Smith, Frank E. Pfefferkorn, and Kevin T. Turner, "Micro End Milling Polystyrene for Microfluidic Applications", ICOMM/4M2010 No. 71

16. Ampara Aramcharoen, Shaw Kah-Chuan Sean and Liu Kui, "An experimental study of micro milling of polymer materials for microfluidic applications", International journal of Abrasive Technology, Vol. 5, No. 4, 2012

Comparative Study of Gear Hobbing Process under Flooded and Minimum Quantity Lubrication (MQL) Techniques using Vegetable Oil and Mineral based Oil: A Review

Arif. S. Pathan
apathan@mgmu.ac.in

Dhannanjay. R. Dolas
ddolas@mgmu.ac.in

MGM University
Chhatrapati Sambhaji Nagar
Maharashtra

ABSTRACT

Spur gears are widely produced in mass production by gear hobbing process as it reduces time and cost of manufacturing of gears. Increasing productivity, improving performance and reducing the cost of high good quality gears is need of today's gear hobbing process, and this can be achieved by doing analysis and by making improvements both in quality and efficiency of gear hobbing process by reducing cost and by maintaining environmental sustainability. The major problem in gear hobbing is heat generation at the cutting teeth zone, various lubrication techniques and cutting fluids can be used to reduce heat generation at cutting zone, thereby increasing the life of hob and also improving the surface finish of gear tooth. In industries mineral based or synthetic cutting fluids are used for lubrication and cooling purpose. Generally, these cutting fluids are used in flooded condition, thereby increasing the manufacturing cost and also effecting the environment due to wastage of waste of large quantity of cutting fluids. Alternative lubrication technique such as minimum quantity lubrication can be used for hobbing process, as this technique can save a lot of cutting fluid as compared to flooded lubrication, also vegetable based cutting fluid can be used instead of mineral based cutting fluid. This work deals with study of Performance assessment of both the lubrication techniques under vegetable based and mineral based cutting fluid in terms of output parameters such as dimensional accuracy, surface roughness, MRR, machining time, machining cost, cutting temperature and environmental impact while manufacturing gears of different materials with different input parameters and different hob materials. Influence of Various input parameters of Hobbing and Lubrication system on output parameters can be studied to analyze the overall performance of hobbing process.

KEYWORDS *: Flooded, MQL, MRR, Dimensional accuracy, Avg.roughness (Ra), Machining cost, Cutting Temperature.*

INTRODUCTION

Spur gears are widely produced by gear Hobbing process, as it saves both cost and time in batch and job type production of spur gears. In Industry there is a huge demand of spur gears, as these gears are widely used in automotive and machinery applications [1]. Gear Hobbing is considered as the easiest method of manufacturing external type of gears such as spur, helical and worm types of gears. The hob is used as cutting tool in gear hobbing process, this hob is available in different sizes depending upon diameter of hob and hobs are available in different materials depending upon type of gear material to be machined. The gear profile is produced by the cutting edges, which are around the hob. In gear hobbing process the most important cutting parameters are, the hob speed (RPM), Feed (Rev/Min), hob Diameter, and the hob material. These parameters are to be selected based on type of gear to be produced, no of teeth on gears and type of gear material. Generally, depth of cut in case of spur gear manufacturing is kept constant, so as improve MRR. For any new gear material to be machined, pilot experiments are conducted to study the influence of input parameters on output response such as dimensional accuracy, surface finish, MRR and machining time [2]. Proper selection of parameters is necessary in order to reduce the cycle time and to improving the productivity by maintaining the quality of gears. Different levels of parameters such as low and medium and high for hob speed, feed, and hob diameter can be selected in order to optimize the parameters for best result [3]. Along with machine parameters, lubrication system parameters and type of cutting fluid to be used are very important in order to reduce friction thereby reducing the cutting temperature. By selecting proper lubrication system and cutting fluid, life of hob can be increased and overall cost of machining can be reduced [4]. Selection of cutting fluids in gear manufacturing depends on various factors such as a. type of work piece material to be machined b. cutting parameters and c. method of application of coolant (Flooded lubrication, Mql, etc.). For example, neat oil is used which has sufficient viscosity to reduce friction and also to remove the heat generated at the tool workpiece interface [5].

METHODOLOGY

In this study, Influence of alternative Lubrication technique i.e., Minimum Quantity Lubrication (MQL) is studied against flooded lubrication using different types of cutting fluids and their performance is also studied in terms of hobbing efficiency, surface roughness, MRR and Dimensional accuracy while hobbing different material using different cutting tool (Hob). Study investigate and compare the performance of gear hobbing under Minimum Quantity Lubrication (MQL) and flooded lubrication by taking input parameters as cutting speed, feed and hob diameter. Output responses such as cutting temperature, surface roughness, machining time MRR and Dimensional accuracy.

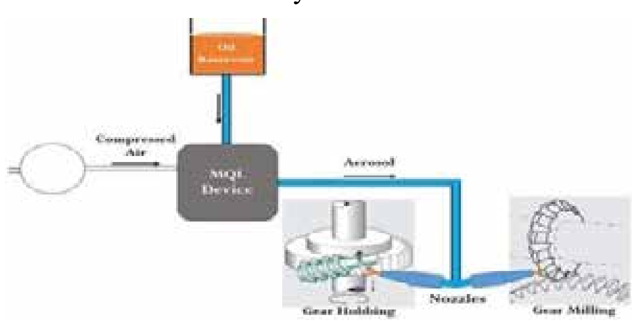

Figure1.Components of MQL System

Minimum quantity lubrication (MQL) is a lubrication technique which can be used in machining processes such turning, milling and gear hobbing to reduce the consumptions of cutting fluid as compared to flooded lubrication. MQL works by supplying minimum quantity cutting fluid as the cutting zone thereby reducing the cutting temperature and friction. MQL provides lubrication and cooling effect as cutting fluid it is directly supplied at the cutting interface with the help of nozzle. In MQL both mineral based and synthetic based oils and vegetable based oils can be used as cutting fluid.

The most important characteristics of MQL are that is eliminates excess use of cutting fluids, thereby reducing machining cost and cutting fluid disposal cost. This technique of lubrication is environmental friendly, as it does not pollute the environment and also reduces soil erosion. MQL as compared to flooded lubrication has many benefits but its performance in terms of machining needs to be evaluated when machining different materials under different input parameters [6]. In MQL a mist of oil and compressed air used to lubricate and cool the work piece. Micro-lubricant particle removes the heat by convention process of heat transfer in case of minimum quantity lubrication machining. Heat transfer coefficient of fluid plays an important in removing the heat from the cutting zone [7]. MQL eliminates the large amount of mineral oil-based cutting oil and replaces it with a small quantity of lubricant mixed with air. In MQL water soluble oil or neat oil such as mineral based or Vegetable based can be used. Performance of Vegetable based oil as cutting fluid can assessed when using this oil in MQL system [8]. The range of cutting fluid flow rate in case of MQL varies from (50–500ml/h). Supplying a small quantity of cutting fluid consumes less power and thus also reduces the total cost [9]. Figure 1. Shows the various components of a MQL system such as oil reservoir, piping system, MQL device and nozzle [10].

Strategies for Sustainable Manufacturing of Gears (Environment-Friendly Lubrication Technique

Application of large quantity of cutting fluids especially mineral-based cutting fluids may leads to environmental hazards, also use of large quantity of fluids is not desirable from economical point of view [5]. Disposal of used cuttingoil is a major issue in flooded lubrication and this can be solved by using environmental-friendly lubrication technique such as minimum quantity lubrication [11]. Bio degradable vegetable based cutting oil can be used instead of mineral based to avoid the environmental hazards of cutting oil [12]. Other techniques of lubrication such as cryogenic can also be used for manufacturing of gears but its overall performance needs to assessed [7]. Vegetable based oils such as soya bean oil and sunflower oil can also be used under flooded and MQL conditions but its economical analysis and performance needs to be assessed [2]. Environment-friendly lubrication techniques include use of vegetable or bio degradable cutting fluids in order to avoid soil erosion [6]. In manufacturing of gears cutting fluid is required to reduce the friction and to provide the lubrication and cooling effect in order to maintain tool life and surface texture of manufactured gears. After manufacturing of gears, these gears are again finished using gear shaping process in order to avoid backlash, noise and vibration. If proper lubrication is provided while manufacturing gears then the manufactured gears will be of good quality, which means less time and effort will be required in gear shaping process and this will indirectly save the cost of manufacturing gears[5]. While using MQL, factors such as chip removing capacity, lubricity, and effect on workpiece and tool life has to be considered [13]. Environment-friendly lubrication technique means lubricants and lubrications techniques that does not harms the environment and also consumes less energy to manufacture the machined components [06]. The summary of various research papers is reported in Table 1.

Table 1. Summary of Literature Survey

Sr. No	Author/ Journal Reference	Objective	Input Parameters	Output Response/ Tool- Workpece Material	Methodology	Result /Discussion	Conclusion
1	Reference: 1 S. V. Shewale and Prof. S. R. Suryawanshi IJERT- Volume: 5 Issue: 2, 2016.	To find optimum input parameters such as hob speed, hob diameter, feed, and hob Material for improving the productivity.	Hob speed- 160,180 and 200 RPM, Hob diameter- 40,50,60 mm, Feed rate, and Hob Material- M2, HSS, D2, Workpiece Material- EN8	Cycle time. Hob Material- M2, HSS,D2, GearMate rial- EN8.	Taguchi method was used to find themost effective parameter in terms of reducing cycle timeof gear hobbing process.	The most effectiveand significant parameters was found to be feed followed by Hob speed. Hob diameter and hob material is found less significant in terms of reducing cycle time of gear hobbing process.	Performance assessment of Gear hobbing can be done in terms of productivity improvement for other gear materialsand at different level of input parameters such as hob speed, feed, hob material, and hob diameter, to find the most optimum value .
2	Reference:2 Vishal Kharka and Kapil Gupta.Elsvier Journal-Jan 2022.	To evaluate and assess performance of spur gear hobbing process in terms of sustainability for three different lubrication conditions i.e. Dry, MQL and Flooded.	Speed of hob 'V' and feed 'f' at three different levels each (i.e., 15, 22 and 29 m/min for speed and 0.32, 0.44 and 0.56 mm/rev for feed).MQL parameters selected were flow rate, nozzle angle and air pressure as 100ml/hr, flow rate 30° and 4 bar.	Microgeo metry variation, tooth surface roughness, MRR. Hob Material was HSS and Gear Material uses was 20MnCr5.	Full factorial method was used to design and conduct the experiments under three different lubrication conditions.	MQL results shows that it is environmental as compared to flooded as it consume very lesscutting fluid, also energy consumption in MQL is found to be less as compared to flooded by about 28 %. In Dry conditions results shows that there is more surface roughness and deviation in gears as compared to flooded and MQL.MRR is found to be more in flooded condition as compared to dry and MQL	MQL shows better performance as compared to flooded and dry lubrication in terms of aspects of sustainability andenvironmental impact social. Whereas flooded lubrication is found to be better in termsof reducing cutting temperature and increasing MRR.

3	Reference: 3 Sujan Debnath and Moola Mohan Reddy Journal of Cleaner produc-tion, Elsvier July 2014.	To study the performance of cutting fluids and lubrications techniques in terms of Environmental factors.	Vegetable based cutting fluid in Flooded lubrication, Vegetable based oil in MQL, Dry Cutting, cryogeni ccutting	Surface Finish, Tool wear, Tool Life, Machining cost	Literature Review	Vegetable oils are considered as environmentally friendly, as it does not harm the environment. It also reduces workers health issues and problems caused by mineral based or synthetic based oil. MQL also shows similar performance under a given range of parameters, but when the range of parameters increases MQL performance decreases. Cryogenic cutting is found to be not economical and feasible in all cutting conditions.	The main advantages of the newly developed vegetable-based cutting oils are high biodegradability and environmentally friendly as compared to mineral-based cutting fluids. The vegetable oils are found to be alternative to conventional cutting fluids when machining under certain range of parameters.
4	Reference: 4 Kapil Gupta and N.K. Jain Journal of Cleaner Production, Elsvier Sept 2015.	To determine efficient technique of gear manufacturing which includes environment-friendly lubricants and lubrication systems which can reduce wastage and minimize energy consumption.	Different lubrication techniques such as cryogenic, MQL. Different types of cutting oils such as synthetic cutting oils and Vegetable based oils.	Green Lubricant s and Lubrication Techniques, Advanced tool material and coatings	Literature Review	It is found that productivity can be increased and hob wear can be decreased under MQL and cryogenic by using Ti-doped AlCrN coated Hob.	High quality and surface integrity of gears along with economic efficiency and environmental sustainability (overall sustainability) can be obtained by using MQL with environment-friendly lubricants and by also by using cryogenic lubrication
5	Reference:5 Wojciech Stachurski Journal of Mechanical andEnergy Engineering Vol.1 May 2017.	To determine the influence of different types of oil with MQL on the wear condition of Hob.	Varying parameters of hob speed, feed and depth of cut with two different oils -Esterified mineral oil and Refined rapeseed oil under MQL Condition.	Hob Wear (Wear of the rake face), Hob Material-High speed steel-HS6-5-2 with module=3, Gear Material-42CrMo4	Experimental Methodology	Result shows that MQL with Esterified mineral oil reduces wear up to20% as compared to Refined rapeseed oil. In Refined rapeseed oil, slightly higher cutting temperatures are obtained as compared to Esterified mineral oil.	MQL with vegetable oil - Refined rapeseed oil does not produce good results as compared to mineral oil but its performance is found to be near mineral oil in terms of MRR and surface finish of gears.

6	Reference: 6 Vishal Kharke jmr&t Journal Elsevier 2020.	To determine variation in total profile of gears and radial runout along with flank roughness so as to assess spur gear quality	Varying parameters of hob cutter speed'V', axial feed 'f' mm/ rev and depth of cut 'd'-at three different levels using MQL Condition by using fatty alcohol- based lubricant.	MRR (mm^3/min), micro geometry deviations(Fa, Fr) and surface roughness(Ra and Rmax) of gears, Hob Material- High speed steel- Emo5Co5 with module=3 and Outer diameter: 80 mm Gear Material- 20MnCr5, Number of teeth: 16, Face width: 10 mm	experiment l investigation using 24 experiments (each parameter at 3 different level to study the influence of input parameters on out response	High quality of gear was found with medium range of hob cutter speed. Low axial feed and medium level of depth of cut; The total profile variation is found to be 49.7 µm;run out error as 117.3 µ m and flank roughness values of Ra as 0.51µ m, and Rmaxas 5.23µ m. MRR increases with increase in Hobbing parameters- V, d,f.	Hobbing parameters and MQL conditions largely influence the surface deviations and surface roughness. Under MQL condition low to medium range of cutting parameters are found to be suitable when machining 20MnCr5 material.
7	Reference: 7 Vivek Rana and Kapil Gupta MDPI Journal Sept 2022	To study the influence of MQL and flooded lubrication for gear hobbing process and to find the range of surface roughness, MRR and deviation	'V'- 15,22,29 m/ min, axial feed 'f'- 0.32,0.44,0. 56 mm/rev, depth of cut 'd'-2.25 mm (Constant). MQL-fatty alcohol- based lubricant, Q =100 ml/h, ά-30◦, P=4 bar Flooded- mixture of water and machining fluid 'Servo cut S' Q=2500ml/h	Total profile deviation 'Fa' Radial runout 'Fra' (µm), Rmax, Ra (µm), MRR, microhard ness, Hob Material- HSS-Emo5Co5 with module=3 and Outer diameter: 54 mm Gear Material- 20MnCr5, Number of teeth: 16, Face width: 10 mm	Full factorial experimental method	The study shows that proves that MQL is capable of manufacturing gears with good accuracy and also better cooling and lubrication. Flooded lubrication performance is found to be better in terms of surface roughness and MRR.	In MQL better lubrication is possible as cutting oil is supplied near to cutting zone. The range of optimum cutting parameters needs to be selected for manufacturing 20MnCr5 gear for increasing productivity and surface finish.
8	Reference: 8 Shouli Suna and Shilong Wang Science direct, Elsvier Journal	To propose a model for predicting the gear hobbing geometric deviations and optimization of gear hobbing process parameters in order to improve the precision of gear hobbing process as well as lower the gear manufacturing cost	Hob parameters- Module (mm) 2.5 Pressure angle (degree) 20 Material M35 Gear parameter- Module (mm) 2.5 Tooth number 18 Pressure angle (degree) 20 Tooth width (mm) 12.5, Machine-5- axis (CNC) gear hobbing	Geometric deviations of left and right gear flank such as (Fα- total profile error, Fβ-total helix error, fp-single pitch, Fp- accumulated pitch error) No. of gears cut-5.	Particle Swarm Optimization and Back Propagation algorithm	The results show that the PSO-BP model improves the predicted accuracy of gear hobbing when compared with actual experimental values of geometric deviations. Graph between PSO predicted geometric deviations and experimentally obtained geometric deviations shows that the error is less than 5%.	The gear hobbing process parameters can be optimized to minimize gear geometric errors, and thus improve the gear manufacturing precision. The optimized. The optimize value of V and f for minimum geometric deviations are found to be 253 Rpm and 0.58 mm/rev. The total deviation of the tooth profile (Fα) is generally considered as the main factor that affects the transmission process.

9	Reference:9 Wojciech Stachurski, Journal of Mechanics and Mechanical Engineering, Research Gate, Vol-16, January 2012. To determine the influence of Minimal Quantity Lubrication (MQL) and flooded lubrication in gear hobbing.	To determine the influence of Minimal Quantity Lubrication (MQL) and flooded lubrication in gear hobbing.	Cutting parameters applied: depth of cut ap=6.6 mm, axial feed f=0.5mm/rev, cutting speed Vc=34m/min, lubricant-MICRO 3000 at the rate of 25 ml per hour in MQL and 10 Litre per minute in flooded. Gear Material-42CrMo4 (20HRC), Hob Cutter - HS6-5-2high speed steel (m=3)	Hob Wear, Cutting forces, Ra	Experimental Methodology	The results indicate that the hob wear rate is similar for the MQL and for conventional flood cooling. This is also confirmed by the measurements of cutting forces, which values are comparable for both methods	The investigations have proved that the application of the MQL method in hobbing is justified. Also, hob wear rate is similar for the MQL and for conventional flood cooling. This is also confirmed by the measurements of cutting forces. Also, efficiency of MQL method of fluid supply should be checked for higher hob wears, and for finishing cutting with low cutting depths.
10	Reference:10 Genbao Zhang Proceedings of the 36th International MATADOR Conference, Springer Journal 2017.	To Select optimal process parameters for gear hobbing under cold air minimum quantity lubrication cutting environment	Speed, feed rate, depth of cut, Qty of lubricant, Air temperature	MRR Cutting Temperature, Hob Wear, surface finish	Taguchi technique	The optimization results indicated that MQL of 40 ml/h, cold air temperature-45°C and a feed rate of 0.2mm/r is essential to simultaneously minimize tool wear and tooth-face roughness.	ANOVA illustrates that quantity of lubrication is the dominant parameter followed by cold air temperature and feed rate in optimizing the machinability. From the Taguchi optimization results, it is found that high MQL is required for minimizing both tooth-face roughness and Tool wear.

Table 2. Performance indicators in Gear Hobbing Process: Given below are the most important Performance indicators in Gear Hobbing process

Sr. No	Performance indicator	Trend in Industry	Measuring Data /Measuring instruments required
1	MRR Dimensional accuracy	High	• Machining time, density of material • Gauging and measurement system.
2	Cycle Time Cutting Temperature Surface Roughness (Ra)	Low	• Machining time in minute or second • Infrared Thermometer • Surface roughness Tester
3	Machining Cost	Low	• Tool cost, coolant cost and material cost
4	Economic Efficiency (In terms of machining cost)	High	• Machining Cost
5	Productive efficiency	High	• Cycle Time (Machining time and MRR)

RESULT AND DISCUSSIONS

Cuttng fluids performance in gear hobbing is very important as it reduces friction and thereby decreases cutting temperature and improves life of hob cutter and surface finish of gear tooth. Vegetable-based cutting fluids are environmentally sustainable and these fluids can produce better performance under selected range of cutting parameters and for low to medium carbon steel materials [9]. Ecological problems caused by conventional cutting fluids needs to assess as this not only harm the environment but also increase the cooling and lubrication cost due to overflowing of fluid [15]. Cryogenic cooling conditions are not feasible in all types of process and for all workpiece material. The high-quality gear was obtained, when hob cutter speed was medium, axial feed was low and depth of was medium while manufacturing gears using MQL conditions. Under flooded condition high ranges of cutting parameters are found to better for improving MRR and reducing cycle time [14]. Hobbing parameters such as V, d, f are capable of manufacturing gears with high accuracy, low hob wear and high productivity along with suitable cutting oil [8].

FUTURE SCOPE OF STUDY

Overall Performance evaluation of hobbing process can be done by considering machining cost and Dimensional accuracy. Bio-based cutting fluids & their performance can be studied for gear hobbing process. Detail investigation can be done to find the benefits of MQL and cryogenic cooling type of techniques for gear hobbing.

Further research on feasibility of different types of vegetable oils such as sunflower, soyabean, neem oil, palm oil etc. with minimal quantity lubrication. Opportunity for research on different types of vegetable oils under varying cutting conditions for better performance. Vegetable based lubricant performance can be assessed using MQL and Flooded lubrication for gear hobbing with different set of gear materials. Vegetable based lubricant performance can be compared in MQL and Flooded lubrication system.

CONCLUSION

In this study, objective was to find the optimum combination of process parameters to manufacture high quality m gears. Gear Hobbing performance evaluation can be done out in terms of various factors such as cycle time, efficiency, and economy etc. for different levels and variation of hob speed, feed, hob material, and hob diameter [14]. The main advantages of the newly developed vegetable-based cutting fluids are high biodegradability, environmentally friendly and economical feasibility. Nearly same performance of these fluids can be obtained under identical cutting conditions as compared to mineral-based cutting fluids [12]. Vegetable oil as cutting fluids has numerous advantages and is a best alternative to mineral based or conventional synthetic cutting fluids. Hobbing parameters and MQL parameters largely affect the gear geometry deviations and flank surface roughness [15]. Depth of cut was generally kept constant in many cases in order to improve MRR and to reduce cycle time. Higher values of hob cutter speed and axial feed are found to be most parameters for surface finish and dimensional accuracy of gears [13]. Gears produced in MQL conditions are found to be of good quality and low cost [16]. This study also shows that MQL is capable for manufacturing low and medium carbon steel gears with better accuracy, good surface finish and smoother operational performance due to its better lubrication action [11]. Conventional mineral based fluids used in gear hobbing have negative impacts on the environment and health of the machine operators thereby affecting the sustainability of the gear hobbing process [16]. It can be concluded from the literature review of research pares that MQL can improve overall performance of a machining process [18]. Selection of proper lubricant with viscosity is very important to obtain superior performance of MQL assisted gear hobbing process because effectiveness of MQL is significantly influenced by properties of the lubricants used besides the gear hobbing process parameters and materials of hobbing tool and workpiece [17]. The use of green lubricants will minimize the harmful effects on the environment and provides safe working environment to the machine operators thus improving sustainability of MQL assisted machining process [20]. In Flooded lubrication vegetable based lubricants can be used to improve sustainability and economic efficiency while manufacturing high carbon steel gears [18]. The results of this study will be very helpful while manufacturing gears considering economic efficiency and environmental sustainability.

REFERENCES

1. S. V. Shewale and Prof. S. R. Suryawanshi "Analysis of Process Parameters in Hobbing using Optimization Technique" IARJSET- Volume: 4 Issue: 1, May 2016.
2. Vishal Kharka and Kapil Gupta "Influence of MQL and hobbing parameters on microgeometry deviations and flank roughness of spur gears manufactured by MQL assisted hobbing" Journal of Materials Research and Technology, Elsvier June 2020.
3. Sujan and Moola Mohan Reddy "Environmentally friendly cutting fluids and cooling techniques in machining: AReview" Journal of Cleaner Production, Elsvier September 2014.
4. Kapil Gupta et.al "Recent developments in sustainable manufacturing of gears: a review" Journal of CleanerProduction, Elsvier September 2015.
5. Wojciech Stachurski "Influence of supplying the vegetable oil with minimal quantity lubrication on wear of thehob during hobbing process of the gears" Journal of Mechanical and Energy Engineering, Volume: 1, April 2017.
6. Vishal Kharka et.al "Influence of MQL and hobbing parameters on micro geometry deviations and flankroughness of spur gear manufactured by MQL assisted hobbing'' jmr&t Journal Elsevier 2020.
7. Vivek Rana and Kapil Gupta "Performance Characteristics of Spur Gears Hobbed under MQL, Flood Lubrication, and Dry Environments" MDPI Journal Sept 2022.
8. Shouli Suna and Shilong Wang "Prediction and optimization of hobbing gear geometric deviations'', Science direct, Elsvier Journal Sept-2017.
9. Wojciech Stachurski "Application of minimal quantity lubrication in gear hobbing'', Journal of Mechanics and Mechanical Engineering, Research Gate, Vol-16, January 2012.
10. Genbao Zhang "Selection of optimal process parameters for gear hobbing under cold air minimum quantity lubrication cutting environment'', Proceedings of the 36th International MATADOR Conference, Springer Journal 2017.
11. Omesh Manuja and Frank Crasta "A Review on Multi Response Optimization on Machining Parameters in Spur Gear Hobbing process by using Taguchi based GRA." IJRMEE- Volume: 4 Issue: 5, May 2017.
12. Vishal Kharka and Kapil Gupta "Influence of MQL and hobbing parameters on microgeometry deviations and flank roughness of spur gears manufactured by MQL assisted hobbing" Journal of Materials Research and Technology, Elsvier June 2020.
13. Tuan Ngo and Vi Hoang "Research on Applying Nano Cutting Oils in Spur Gear Hobbing Process" World Journal of Engineering and Technology, May 2017.
14. Y.M. Shashidhara, S.R. Jayaram "Vegetable oils as a potential cutting fluid—An evolution" Tribology International Journal Elsvier, January 2010.
15. Shewale and Suryawanshi "Productivity Improvement of Gear Hobbing Process by Analyzing Process Parameters" International Journal of Engineering Research & Technology, Volume 5, Issue 2, 2017.
16. Vishal Kharka et.al "Performance Characteristics of Spur Gears Hobbed under MQL, Flood Lubrication, and Dry Environments" MDPI Journal, Septemmber-2022.
17. Sujan Debnath et.al "Environmental friendly cutting fluids and cooling techniques in machining: A Review"Journal of Cleaner Production, Elsvier September 2014.
18. Luiz Arthur and Alessandro Silveira "Comparative LCA of Automotive Gear Hobbing Processes with FloodLubrication and MQL" Research Square Journal 2003.
19. Thomas Bergs and Felix Kuhn "Analysis of the tooth root roughness of hobbed gears'', Science direct, ElsvierJuly2019.
20. Vishal Kharka and Neelesh Jain "Performance comparison of green lubricants in gear hobbing with minimum quantity lubrication'', Science direct, Elsvier Journal April-2022.

Advancement and Future Prospect of Solar Energy in India: A Comprehensive Review

Swanand Joshi
✉ swanand.joshi@vpmmpcoe.org

Hrishikesh Bhave
✉ hrishikesh.bhave@vpmmpcoe.org

Jitendra Acharya
✉ jitendra.acharya@vpmmpcoe.org

Department of Mechanical Engineering
VPM's Maharshi Parshuram College of Engineering
Velneshwar, Maharashtra

ABSTRACT

This comprehensive review explores the status, challenges, and future prospects of solar energy in India. Numerous important topics are covered in the research, such as evolving business models, market dynamics, governmental frameworks, and solar energy technology. With an abundance of solar resources, India has seen a notable increase in solar capacity thanks to programs like the National Solar Mission. However, issues like sporadicness, high initial prices, and technological impediments continue to exist. In analysing the changing legislative environment, the study highlights the goals, accomplishments, and funding sources of the National Solar Mission. Initiatives at the state level and regulatory issues are closely examined, especially those about grid integration and net metering regulations. The overview of the solar energy market includes information on financing options, investment patterns, and new business models such as solar rooftop leasing and solar as a service (SaaS). The study includes benefits like lower carbon emissions, energy independence, and the creation of jobs in addition to drawbacks like erratic results and expensive initial expenditures. In this study, the future of solar energy in India is discussed with an emphasis on high goals, declining prices, technical developments, higher investments, and integrating solar with developing technologies. The study's conclusions highlight solar energy's ability to spearhead India's sustainable energy transition and acknowledge its contribution to job creation, economic expansion, and environmental preservation.

KEYWORDS *: Solar energy, Solar rooftop leasing, Solar as a Service (SaaS), National solar mission, Renewable energy*

INTRODUCTION

India is a country that is poised for revolutionary change, located at the crossroads of population dynamics, economic growth, and the need for sustainable development1. India's economy, which is among the fastest-growing in the world, has seen a sharp increase in energy consumption due to factors such as urbanization, industrialization, and population growth. In addition to creating affluence, this unheard-of expansion has made it more important than ever to have a strong and stable energy infrastructure to power advancement engines.

An important factor in this paradigm change has been the development of renewable energy sources. India's leadership in solar power generation has gained international recognition thanks to the government's National Solar Mission. But there are certain complications with this move. Because renewable energy sources are intermittent, grid stability is impacted, which calls for advancements in energy storage technology. For the energy infrastructure to keep up with the changing needs of a fast-expanding economy, significant investments and modernization are needed. India's journey through this complex landscape of environmental obligations and economic ambitions is reflected in the energy sector, which has become a melting pot where the country's commitment to global climate objectives and sustainable development meets. This comprehensive review seeks to delve into the intricacies of India's energy situation, exploring the advancements, challenges, and future prospects that define this critical juncture in the nation's energy trajectory.

SITUATION OF ENERGY IN INDIA

The dynamic interaction of several elements, influenced by India's fast economic growth, growing population, and the need to address energy security and environmental sustainability, describe the country's energy status2. India's energy environment is characterized by a heavy reliance on fossil fuels, with coal making up most of the energy mix. In the past, this has been necessary to fulfil the growing power demand and provide energy access throughout a large and populated country. However, there are environmental problems because of this reliance on traditional sources, such as air pollution and greenhouse gas emissions.

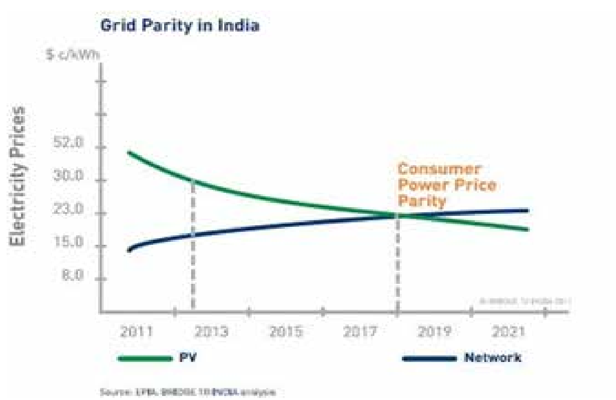

Figure 1: Energy Situation in India (https://energypedia.info/wiki/India_Energy_Situation)

A discernible trend toward portfolio diversification in the energy sector has been observed in recent years, with a rising focus on renewable energy sources3. The government's ambitious National Solar Mission and other renewable energy projects have greatly aided this transformation. Particularly in solar energy, significant progress has been made, and India is now among the world leaders in producing solar electricity4. The nation has significantly increased its solar capacity because of the large expenditures it has made in photovoltaic technology. A more sustainable and cleaner energy future is also facilitated by the substantial contributions that hydropower and wind energy make to the renewable energy industry.

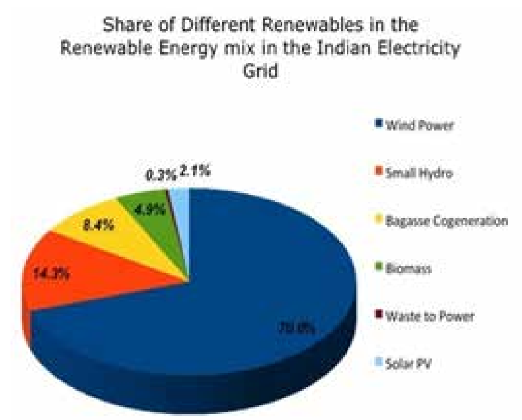

Figure 2: India Energy Situation (https://energypedia.info/wiki/India_Energy_Situation)

POLICY FRAMEWORKS AND REGULATORY LANDSCAPE

National Solar Mission (NSM)

Launched in 20107, the National Solar Mission (NSM) is a key policy framework that has greatly influenced the solar energy sector in India. The NSM sets aggressive goals for the expansion of solar capacity and is envisioned as a comprehensive plan to harness solar power and lessen the country's reliance on foreign energy sources8. Promoting sustainable growth, improving energy security, and reducing the environmental effects of energy generation are the main goals of the mission.

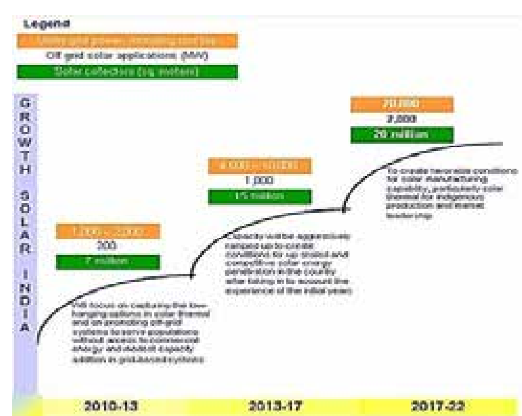

Figure 3 : Growth of Solar energy in India[9]

The NSM's set of precise goals for increasing solar capacity expressed both in megawatts and as a share of the overall energy mix, is one of its main tenets. The mission has seen significant progress over the years, with installed solar capacity growing significantly and solar energy output increasing10. These successes demonstrate how well the NSM is working to get India closer to a future with more renewable and sustainable energy sources.

REGULATORY CHALLENGES AND REFORMS

Reforms and regulatory obstacles are important factors affecting how solar energy develops in India13. The smooth integration of solar energy into the current electrical infrastructure is one of the biggest obstacles. Grid stability is threatened by the unpredictability of solar power output, necessitating creative fixes and infrastructure enhancements14. It is imperative to address these problems to guarantee a robust and dependable energy supply.

Furthermore, there are advantages and disadvantages to net metering rules, which are intended to encourage the use of solar energy. Although net metering enables customers to send excess solar power back into the grid to reduce their electricity costs, different areas may find different rules to be more efficient than others15. To promote the broad use of solar rooftop systems among residential and business consumers, it is imperative to examine and improve these rules. To support sustainable growth, the regulatory landscape must change to find a balance between advancing solar energy and resolving technological and financial issues. Ongoing regulatory changes will be crucial in determining the future of the solar business and guaranteeing its contribution to India's energy transition as it grows.

MARKET DYNAMICS AND INDUSTRY TRENDS

Solar Energy Market Overview

Recent years have seen the solar energy business in India develop and change dramatically, establishing it as a major participant in the world's renewable energy scene. The market has grown significantly as a result of favorable legislative conditions and technical developments, turning it into a hub for developers, investors, and innovators. Achieving energy security, cutting carbon emissions, and promoting sustainable development are the main objectives that have driven India's solar energy sector to the forefront of the country's energy transformation.

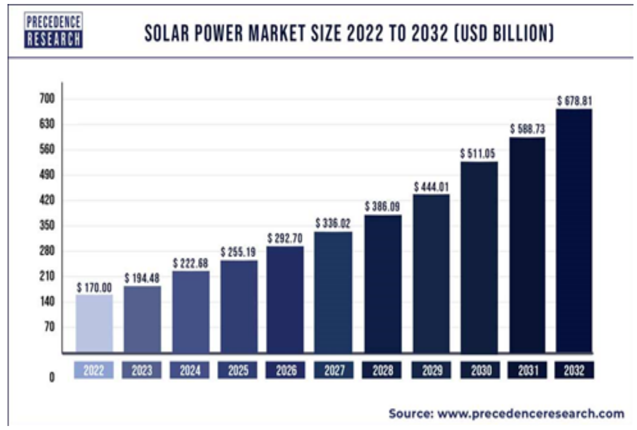

Figure 4: Solar power market size from 2022 to 2032. (https://www.precedenceresearch.com/solar-power-market)

The market summary demonstrates a strong rise in installed solar capacity, which is fueled by both distributed and utility-scale solar projects. The National Solar Mission in particular has been instrumental in setting high goals and fostering an environment that is conducive to solar investment16. Due to the competitive price of solar energy and the falling costs of photovoltaic technology, the industry is growing and solar power is becoming more and more appealing to consumers.

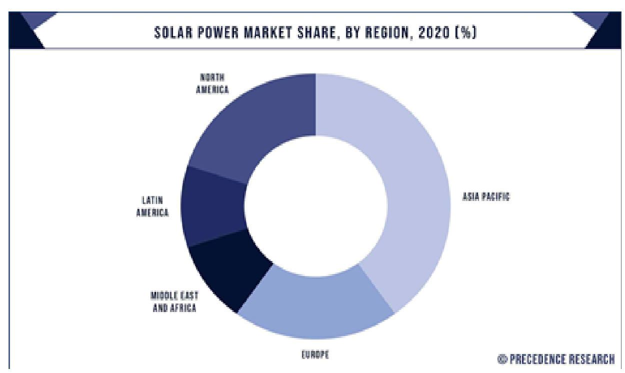

Figure 5: Solar power market share by region, 2020 (https://www.precedenceresearch.com/solar-power-market)

However, there are still difficulties, such as the requirement for sophisticated energy storage systems, intermittency problems, and complicated grid integration. The overall outlook for the solar energy business is positive despite these obstacles as continued research and development is propelling technical advancements. India is aiming to have a more diverse and sustainable energy portfolio, and the solar energy industry is expected to be a key player18 in both supplying the country's increasing energy needs and making a major contribution to worldwide efforts to tackle climate change.

Investment and Funding Landscape

The solar energy industry in India is characterized by a dynamic and ever-evolving ecosystem that has drawn substantial money from a range of domestic and foreign sources, as seen by the finance and investment landscape19. The industry has seen a boom in investment over the last ten years, fueled by technology improvements, favorable government regulations, and rising public awareness of the financial and environmental advantages of solar energy.

Venture capital and private equity companies have also demonstrated a strong interest in the solar sector in India, making investments in cutting-edge businesses and technology that are centred around solar energy solutions21. This infusion of private cash has broadened the funding environment and expedited technology breakthroughs, resulting in a more robust and sustainable solar economy.

Emerging Business Models

Solar Rooftop Leasing

Particularly in urban and heavily populated regions, solar rooftop leasing has arisen as a cutting-edge business model that is completely changing the landscape of solar energy adoption22. This approach tackles a major issue that affects customers in the residential, commercial, and industrial sectors: the initial outlay of funds needed to install solar panels. Under a solar rooftop leasing contract, the cost of buying, setting up, and maintaining solar panels on the customer's property is borne financially by a third-party solar provider.

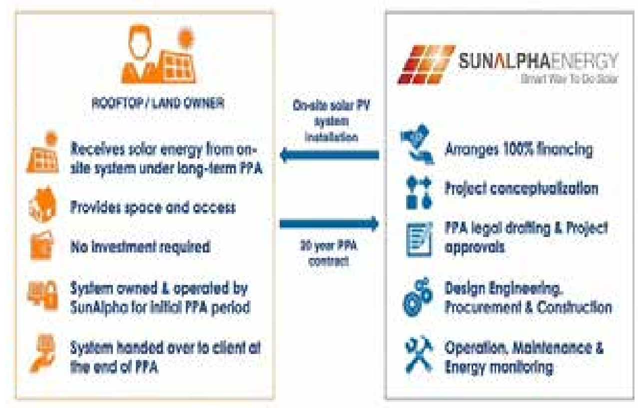

Figure 6: Future of Solar leasing in India (https://www.greenworldinvestor.com/2017/09/12/future-of-solar-leasing-in-india-advantages-and-leading-players/)

To use the solar panel system, the customer usually enters into a lease arrangement with the solar supplier, paying a set monthly price in exchange. This charge takes care of the equipment, installation, and continuing maintenance charges. Customers who want to lease solar rooftops can take advantage of solar energy without having to make a sizable upfront commitment. This strategy democratises solar power access, opening up the renewable energy transition to a larger range of people and companies.

Solar As A Service (SaaS)

The business model known as "Solar as a Service" (SaaS) is radically changing the way solar energy is deployed, particularly for commercial and industrial organisations24. Under the SaaS model, solar developers or service providers take on responsibility for the ownership, management, and upkeep of solar systems on their clients' properties. This eliminates the need for large upfront financial investments and the hassles of system ownership, giving companies access to solar electricity.

Electricity purchase agreements (PPAs), in which the client consents to purchase the solar power produced by the system at a fixed rate for a given length of time, are the foundation of the software as a service (SaaS) business model25. This cost is frequently set below the current grid electricity rates, offering businesses a strong financial incentive to switch to sustainable energy sources.

ADVANTAGES AND DISADVANTAGES OF SOLAR ENERGY IN INDIA

Advantages of Solar Energy in India

There are several advantages of solar energy in India as follows:

- Abundant Solar Resources: India is a great place to use solar energy since it receives enough sunlight all year round26. The nation offers a huge supply of undeveloped solar potential, which may be used to generate renewable energy.
- Reduced Carbon Emissions: One clean and environmentally friendly energy source that greatly lowers greenhouse gas emissions is solar electricity. Solar energy is essential to India's efforts to tackle climate change as it helps the country meet sustainability targets and take care of the environment.
- Energy Independence: Reliance on foreign energy sources and fossil fuels is lessened with the use of solar energy27. India may improve its energy security and decrease its susceptibility to swings in the global energy market by utilising solar electricity generated locally.
- Job Creation: From production and installation to maintenance and research, the solar energy industry has the potential to create jobs at several points in the value chain28. Both social progress and economic prosperity may benefit from this.
- Low Operating Costs: Solar power systems are rather inexpensive to operate and maintain once built. The cost of producing solar energy has fallen down overall because to technological breakthroughs and falling solar panel prices.

Disadvantages of Solar Energy in India

There are several disadvantages of solar energy in India as follows:

- Intermittency and Weather Dependency: Because solar energy generation depends on sunshine, it is sporadic and weather-dependent. Cloudy days and nights cause little to no electricity to be generated, hence energy storage devices are required to provide a steady supply of power.
- High Initial Costs: Installing solar power systems might require a large upfront investment, despite the cheap operating expenses. Widespread adoption may be hampered by this cost aspect, yet government subsidies and incentives are intended to lessen the difficulty.
- Land Requirement: Large-scale solar projects can need a lot of land, which could cause conflicts with other uses of the property29. It is a task that requires careful thought to strike a balance between other land demands and the requirement for renewable energy.
- Technological Challenges: Challenges facing solar technology include grid integration, energy storage developments, and efficiency improvements. Maximizing the potential of solar energy in India requires overcoming these technological obstacles.
- E-Waste Generation: The production and elimination of solar panels have the potential to augment electronic waste30. Reducing the negative environmental effects of solar technology requires the development of efficient recycling techniques and e-waste management.

FUTURE PROSPECTS

It was demonstrated by Graphene Flagship researchers that employing few-layer MoS2 flakes as an active buffer interface layer may greatly extend the lifespan of perovskite solar cells 31.The future of solar energy in India holds immense promise and is poised for significant growth, driven by various factors:

- Ambitious Targets and Policies: India has established aggressive goals to increase its solar energy capacity, as seen by programs such as the National Solar Mission (NSM). The solar energy industry will advance if these regulations are maintained and even more ambitious goals are announced.
- Falling Costs: Solar energy has been getting cheaper over time, which makes it more and more competitive with other energy sources. It is anticipated that the cost of solar electricity will continue to decline as economies of scale and technological advancements take effect, making it a more alluring choice for broad use.

- Technological Advancements: More affordable and efficient solar panels are anticipated because of ongoing research and development in solar technology. Improvements in energy storage, smart grids, and grid integration will raise the efficiency and dependability of solar energy systems even more.
- Energy Storage Solutions: Progress in energy storage technology, such as batteries, is increasingly essential to mitigating the intermittent nature of solar power generation[32]. The use of energy-efficient storage systems will improve grid stability and provide a more consistent and dependable solar power supply.
- Increased Investments: India's solar energy industry is drawing large amounts of funding from both local and foreign investors. Funding will be essential to the sector's growth as financial institutions and investors realise the solar projects' long-term potential and sustainability.
- Decentralized Energy Production: With solar energy, towns and companies may produce their electricity, contributing to the shift towards decentralised energy production33. This change promotes a more robust and inclusive energy environment and is consistent with the idea of energy democratisation.
- Job Creation: It is anticipated that the solar energy industry will expand and provide jobs in several sectors, including manufacturing, installation, maintenance, and research. Both social progress and economic growth are aided by the creation of jobs.

CONCLUSION

Conclusively, this wide subject highlight the complex terrain of solar energy in India, scrutinising its present condition, obstacles, and prospective course. India has risen to prominence in the world of renewable energy because to its plentiful solar resources and bold projects like the National Solar Mission. The assessment has clarified the astounding rise in solar capacity, which has been fueled by investment growth, cost reductions, and supporting regulations. Even with the advancements, there are still obstacles to overcome, such as sporadic problems, expensive initial expenses, and technical limitations. But legislative frameworks, regulatory environments, and new business models—like solar rooftop leasing and Solar as a Service (SaaS)—all point to smart methods to get over these obstacles and promote long-term growth. Future prospects for solar energy in India seem bright, with high goals, rapid technology development, and greater international cooperation. The industry is going through a revolutionary era, as seen by declining costs, rising community solar projects, and solar's integration with developing technology. Solar energy is positioned as a key component of India's energy transformation due to its potential for job creation, economic development, and environmental sustainability.

Realizing the full potential of solar energy and guiding the country towards a cleaner, more sustainable energy future will depend greatly on India's continued commitment to creative policies, technological advancements, and international partnerships as it pursues its goals of energy security, economic growth, and environmental stewardship.

REFERENCES

1. Dhanda, S.K., 2018. Rising India. World Affairs: The Journal of International Issues, 22(3), pp.60-81.
2. Avtar, R., Tripathi, S., Aggarwal, A.K. and Kumar, P., 2019. Population–urbanization–energy nexus: a review. Resources, 8(3), p.136.
3. Akrofi, M.M., 2021. An analysis of energy diversification and transition trends in Africa. International Journal of Energy and water resources, 5(1), pp.1-12.
4. Raina, G. and Sinha, S., 2019. Outlook on the Indian scenario of solar energy strategies: Policies and challenges. Energy Strategy Reviews, 24, pp.331-341.
5. Tan, K.M., Babu, T.S., Ramachandaramurthy, V.K., Kasinathan, P., Solanki, S.G. and Raveendran, S.K., 2021. Empowering smart grid: A comprehensive review of energy storage technology and application with renewable energy integration. Journal of Energy Storage, 39, p.102591.
6. Sovacool, B.K., 2019. Energy security: challenges and needs. Advances in Energy Systems: The Large-scale Renewable Energy Integration Challenge, pp.111-118.

7. Behuria, P., 2020. The politics of late late development in renewable energy sectors: Dependency and contradictory tensions in India's National Solar Mission. World Development, 126, p.104726.

8. Jha, V., 2023. The Making of the International Solar Alliance: India's Moment in the Sun. Oxford University Press.

9. Pathak, P. and Singh, A., 2014. Solar Power as a Source of Ecologically Sustainable Growth in Rajasthan. SAMRIDDHI: A Journal of Physical Sciences, Engineering and Technology, 5(02), pp.131-136.

10. Nguyen, X.P., Le, N.D., Pham, V.V., Huynh, T.T., Dong, V.H. and Hoang, A.T., 2021. Mission, challenges, and prospects of renewable energy development in Vietnam. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, pp.1-13.

11. Joshi, G. and Yenneti, K., 2020. Community solar energy initiatives in India: A pathway for addressing energy poverty and sustainability?. Energy and Buildings, 210, p.109736.

12. Samal, O.P. and Prajapati, P., The Future of Solar Energy in The Indian Economy.

13. Rathore, P.K.S., Rathore, S., Singh, R.P. and Agnihotri, S., 2018. Solar power utility sector in india: Challenges and opportunities. Renewable and Sustainable Energy Reviews, 81, pp.2703-2713.

14. Amir, M. and Khan, S.Z., 2022. Assessment of renewable energy: Status, challenges, COVID-19 impacts, opportunities, and sustainable energy solutions in Africa. Energy and Built Environment, 3(3), pp.348-362.

15. Smith, J.T., Patty, G. and Colton, K., 2018. Net Metering in the States A primer on reforms to avoid regressive effects and encourage competition.

16. Hansen, U.E., Nygaard, I., Morris, M. and Robbins, G., 2020. The effects of local content requirements in auction schemes for renewable energy in developing countries: A literature review. Renewable and Sustainable Energy Reviews, 127, p.109843.

17. Muthumala, H.S., 2023. An investigation into energy as-a-service (EaaS) business model in facilitating Australian energy transition (Doctoral dissertation, RMIT University).

18. Majid, M., 2020. Renewable energy for sustainable development in India: current status, future prospects, challenges, employment, and investment opportunities. Energy, Sustainability and Society, 10(1), pp.1-36.

19. Talwar, S., 2022. Circular economy initiatives in Indian manufacturing: an ecosystem view (Doctoral dissertation, Macquarie University).

20. Aggarwal, M. and Dutt, A., 2018. State of the Indian Renewable Energy Sector: Drivers, Risks, and Opportunities. Council on Energy, Environment and Water.

21. Nedayvoda, A., Mockel, P. and Graf, L., 2020. Deep tech solutions for emerging markets.

22. Adewumi, A., Usman, F.O., Okoli, C.E. and Olu-lawal, K.A., 2024. Solar energy innovations in the USA: A comparative global review. International Journal of Science and Research Archive, 11(1), pp.1528-1539.

23. Sigrin, B.O. and Mooney, M.E., 2018. Rooftop solar technical potential for low-to-moderate income households in the United States (No. NREL/TP-6A20-70901). National Renewable Energy Lab. (NREL), Golden, CO (United States).

24. Bisaga, I., 2021. Innovation for off-grid solar rural electrification. In Affordable and Clean Energy (pp. 783-793). Cham: Springer International Publishing.

25. Gupta, J., Jain, S. and Chakraborty, S., 2023. Open-Source Electricity Trading through the Lenses of a Developing Country. Iranian Journal of Electrical & Electronic Engineering, 19(4).

26. Kumar, C.M.S., Singh, S., Gupta, M.K., Nimdeo, Y.M., Raushan, R., Deorankar, A.V., Kumar, T.A., Rout, P.K., Chanotiya, C.S., Pakhale, V.D. and Nannaware, A.D., 2023. Solar energy: A promising renewable source for meeting energy demand in Indian agriculture applications. Sustainable Energy Technologies and Assessments, 55, p.102905.

27. Berdysheva, S. and Ikonnikova, S., 2021. The energy transition and shifts in fossil fuel use: the study of international energy trade and energy security dynamics. Energies, 14(17), p.5396.

28. Ram, M., Aghahosseini, A. and Breyer, C., 2020. Job creation during the global energy transition towards 100% renewable power system by 2050. Technological Forecasting and Social Change, 151, p.119682.

29. Majumdar, D. and Pasqualetti, M.J., 2019. Analysis of land availability for utility-scale power plants and assessment of solar photovoltaic development in the state of Arizona, USA. Renewable Energy, 134, pp.1213-1231.

30. Aboughaly, M. and Gabbar, H.A., 2020. Recent technologies in electronic-waste management. E-waste Recycling and Management: Present Scenarios and Environmental Issues, pp.63-80.

31. Capasso, A., Matteocci, F., Najafi, L., Prato, M., Buha, J., Cinà, L., Pellegrini, V., Carlo, A.D. and Bonaccorso, F., 2016. Few-layer MoS2 flakes as active buffer layer for stable perovskite solar cells. Advanced Energy Materials, 6(16), p.1600920.

32. Rahman, M.M., Oni, A.O., Gemechu, E. and Kumar, A., 2020. Assessment of energy storage technologies: A review. Energy Conversion and Management, 223, p.113295.

33. Piterou, A. and Coles, A.M., 2021. A review of business models for decentralised renewable energy projects. Business Strategy and the Environment, 30(3), pp.1468-1480.

Supplementary Treatments Applied in Friction Stir Welding Process: A Review

Hrishikesh Bhave
✉ hrishikesh.bhave@vpmmpcoe.org

Rahul Kundiya
✉ rahulkundiya31@gmail.com

Department of Mechanical Engineering
VPM's Maharshi Parshuram College of Engineering
Velneshwar, Maharashtra

ABSTRACT

This research focuses on a detailed analysis of several recent supplemental treatments used to friction stir welding (FSW). It includes annealing, isothermal ageing, solution heat treatment, mechanical powder mixing, accumulative roll-bonding, retrogression and retrogression & reaging application of high-power diode laser arrays for pre/post-weld heating during FSW, and instantly pouring water. Ultrasonic assisted ageing is also covered, along with the introduction of the shielding gas around the tool. The distribution of the microstructures, change in microstructural and mechanical characteristics, and hardness are all reviewed. The impact of the FSW technique on the size of the matrix grain and the reinforcing particles is assessed. The study focuses on the development of intermetallic compounds under the impact of a powerful ultrasonic vibration process. Analysis of the flow structure is done. It is also examined how single-pass friction stir processing (SPFSP) and multi-pass friction stir processing (MPFSP) affect the mechanical characteristics and microstructure. This research emphasises a thorough literature review based on the various current FSW supplementary treatments and their influences on microstructure and mechanical properties.

KEYWORDS *: FSW, Green technology, Supplementary treatments, Mechanical properties.*

INTRODUCTION

FSW is a green solid state welding process used for joining of similar and dissimilar materials. A non-consumable tool pin is used in the friction stir welding (FSW) method to join two facing sections of workpiece material. Heat is produced as a result of friction between the rotary tool and the surface of the workpiece material, resulting in a softened region adjacent to the FSW tool. It is a new method of joining that is used to combine soft materials like alloys and aluminium. Currently, FSW works in a variety of sectors, including the railway, automobile, aircraft, and maritime. It was originally used to join soft materials. These days, high melting- temperature tool materials like titanium, nickel, and steels are joined using this procedure. It becomes difficult because the basis ingredients of two distinct materials differ in their chemical composition and mechanical characteristics. If the parameters are not appropriately chosen and treatments are not carried out, FSW has some flaws like poor corrosion resistance, tunnel fault, cavity, and void. In order to prevent or minimise such faults, various supplementary treatments are reviewed in this study, along with characterisation of the mechanical and metallurgical propertie [8 -14, 24-26].

LITERATURE REVIEW

Y.S. Sato et al, [1] conducted research on accumulative roll-bonded aluminum alloy grade 1100 that was 3 mm thick. ARB is the only current intense straining technology that can make huge, bulky materials by applying serve plastic strain to metallic materials. The accumulative roll-bonding during FSW may successfully prevent softening.

Huseyin Uzun et. Al. [2] employed AA2124/SiC/25p composite materials that were 6 mm thick. This composite was made by mechanical powder mixing with pressing of hot and then forging. Solution heat treatment (T4 temper) was used to treat the forged composite plating. The base material and the weld zone both include a relatively uniform distribution of fine and coarse SiC particles, according to EDX tests. In the weld nugget, the FSW can produce regions with high densities of tiny SiC particles. Additionally, the weld nugget displays considerable coarse SiC particle breaking. The average hardness value of the parent composite is 250 Hv. The weld nugget has somewhat higher average hardness values than the TMAZ. The electrical conductivity results gave a good indication that the AA2124/SiC/25p composite had an FSW seam.

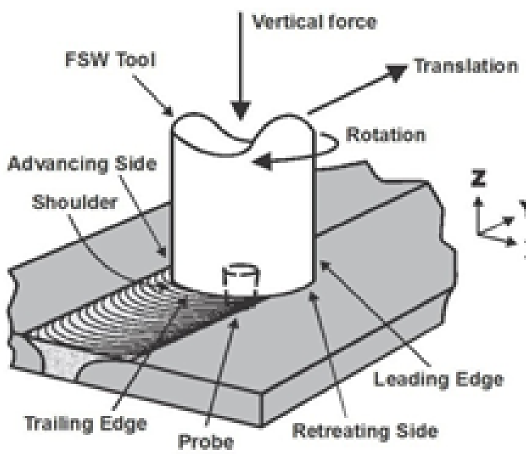

Fig.1 Schematic of friction stir welding process.

P. Vijaya Kumar et al [3] analysed the impact of post-FSW treatment on the mechanical properties, including peak ageing (T-6), overaging (T-73), retrogression, and retrogression & reaging (RRA). Their research found that the stress corrosion cracking resistance is improved with the least amount of strength loss when materials are overaged (T73) from peak aged (T6) conditions. Welds may receive a T6 treatment if corrosion is not an issue.

Alexander et al. [4] the FSW on hot-rolled AA 2024 aluminium alloy that is 10 mm thick. 32.28 KN of axial pressure was used. While FSW, ultrasonic aided ageing treatment was applied. As a result, the UAFSW sample has a more consistent microhardness distribution across the weld zones than the traditional FSW samples, and as a result, the weld joint was too much stronger. Metal in UAFSW TMAZ and HAZ has a microhardness that is noticeably lower than in the corresponding FSW zones. Porosity was significantly reduced by UAFSW. The size of the stir zone was same for the both weld zones. The thermomechanically affected zone area of the UAFSW was 21% greater than the FSW weld joint. It supports for the reduction of the metal's operational viscosity by the acoustoplastic effect. The overall area of heat affected zone in UAFSW was less than that of FSW weld joint. While UAFSW has an 8% smaller total area taken up by the three zones.

Sergei Tarasov et al, [5] Al-Cu-Li-Mg aluminium alloy that was 2 mm thick was subjected to an ultrasonic study of the FSW. 70 and 60 KN of axial pressure were applied. They discovered through their research that an ultrasonic vibration application created a homogeneous vibration velocity and it's distribution along and across the weld joint. It reduces the size of the recrystallized grains in the weld joint stir zone.

Masoud Jabbari et. al. [6] studied the FSW experiment using 4 mm thick pure copper and 1350 aluminium plates. Before welding, the plates were annealed for two hours at 400°C. Their experiment's findings validated that increased in tool rotational speed causes the grain size in the nugget zone to grow. Maximum hardness was attained at 900 rpm of rotation. At this tool rotational speed the maximum strength and the least amount of elongation of the weld joint were produced.

subsequent post-FSW heat treatment as well as the naturally aged temper. Their investigation revealed that-1) at a temperature of 200°C the initially present clusters were dissolve and do not reform after welding process due to lack of vacancies. At the temperature range of 250°C– 300°C the precipitation of platelet phases was most prominent after welding process and these temperatures temperature ranges. 2) When put under heat treatment after welding, the various weld zones show highly distinct ageing kinetics. 3) After the treatment T3 to a post-FSW T8 heat treatment the hardness heterogeneity was noticed significantly. These changes in hardening kinetics explain this heterogeneity.

P.M.G.P. Moreira et al, [15] welded aluminum alloy 6061-T6 and aluminum alloy 6082-T6 by FSW. The artificial ageing at T6 condition was provided. They achieve a junction that is devoid of defects and has the same qualities as the underlying material.

T. Saeid et al, [16] used 2205 duplex stainless steel that is 2 mm thick for FSW. Axial pressure of 14 KN was used for the procedure. To prevent surface oxidation, Ar shielding gas was passed around the tool. Sound weld joints were created for 50 to 200 mm/min traverse speed. A groove like defect was observed at 250 mm/min traverse speed as insufficient heat input was obtained. The interaction between the welding speed and the peak temperature in FSW is taken into consideration when interpreting these results.

Olivier Lorrain et al, [17] They employed 4 mm thick, T-6 rolled Aluminium Alloy 7020 in their experiment. Axial pressure of 1200 kg was used during the procedure. Unthreaded pin material flow was discovered to have the same characteristics as material flow utilising traditional threaded pins; material placed on the bottom section of the weld's retarding side (RS) and the weld's advancing side (AS), respectively; The tool is surrounded by a layer that rotates. The plunge force and the tool rotational speed the area of tool shoulder dominated zone. The cylindrical tapered pin flats can lessen this effect.

P. Prasanna et al, [18] utilised AA6061 aluminium alloy plate that was 5 mm thick and had undergone annealing and normalising heat treatment. 14 KN of axial pressure was applied during the FSW process. In the hexagonal pin profile tool, hardness was greater. The weld joints exhibits highest tensile strength.

M. Thoma et al, [19] Die cast alloys Al and Mg that were 3.3 mm thick were used to study the FSW process. The procedure was carried out using ultrasonic technology. The procedure was carried out at a single location. The weld nugget shape and the microstructure of the welded joint are affected by ultrasonic vibrations. The joining materials were homogeneously mixed inside the weld nugget zone with the assistance of ultrasonic vibrations. The contact between magnesium and nugget was discovered to have two continuous intermetallic layers. The more vigorous swirling of the material at the connecting region was immediately noticeable to US- FSW.

Sunil Sinhmar et al, [20] studied the FSW process with 5 mm thick aluminum alloy 7039. The FSW method involved multiple passes. According to their analysis, the grain size and structure of the weld zone processed by earlier passes was somewhat coarsened by the multi-pass friction stir processing (MPFSP). While the ultimate and yield strengths suffered, the ductility increased from 13.5% to 23.6%. As a result, the longitudinal direction of ductility is higher than the traverse direction. Greater hardness is produced by the multi-pass friction stir processing (MPFSP) compared to the single pass friction stir processing (SPFSP). In comparison to the untreated alloy, stir-processed AA 7039 has a reduced friction hardness.

Table 1: Summary of Literature Review

Sr No	Name of author	Material	Thick ness	Tool rotational speed	Welding speed	Supplemen- tary Treatment	Material characterization & mechanical properties
1	Y.S. Sato et. al.	Al alloy 1100	3 mm	500 rpm	12mm/s	ARB	The AR Bed material's hardness has been significantly reduced. Small hardness reductions were observed in the TMAZ and the stir zone. [21-23]
2	Huseyin Uzun et al	AA2124/ SiC/ 25p	6 mm	800 rpm	120 mm/ min	Mechanical powder mixing. T-4 temper.	Some coarse SiC particles crack and was visible in the stir zone of the weld joint

3	P. Vijaya Kumar et. al.	AA 7075	8 mm	750 rpm	40 mm/ min	1) T-6 2) T-73 3) Retrogression 4) Retrograssion and reageing	1) Under the Retrogression treatment condition, the yield strength and failure time were 184 days and 341 MPa, respectively. 2) In the instance of the RRA condition, it was 175 days and 420 MPa.
4	Alexander et al	AA 2024 Al alloy	10 mm	1000 rpm	200 mm/ min	Ultrasonic assisted aging	Tensile strength 156 MPa. Uniform distribution of hardness throughout the weld joint zones.
5	Sergei Tarasov et al	Al-Cu-Li-Mg	2 mm	600 rpm	300 mm/ min	Ultrasonic application	Tensile strength 122 MPa.In fatigue testing, US-FSW joints achieve noticeably longer lifetimes under the same stress.
6	Masoud Jabbari et. al.	Pure copper / 1350 aluminum alloy	4 mm	400,600, 900,1200& 1500 rpm	25 mm/ min	Annealing before FSW.	In the nugget zone, the increased tool rotational speed which causes to raise the grain size.
7	B. Malard et.al.	AA 2050 T34	20 mm	400 rpm	200 mm/ min	AA 2050 Al-Cu-Li alloy natural aging and tempering.	1) Around 200°C and 230°C are two crucial temperature ranges where early clusters dissolve but do not reform following welding. 2) When put under heat treatment after welding, the various weld zones show highly distinct ageing kinetics.
8	N.T. Kumbhar et. al	Al 5052	5 mm	1120 & 1400 rpm	60,80, 100 mm/ min	Partially recrystallized aluminium 5052 alloy plates	The specimens were fractured in ductile mode of failure.
9	Mostafa S.S. et. al.	AA 6061-O	8 mm	400, 500 & 630 rpm	25 & 40 mm/min	Post FSW heat treatment immediately after FSW of heating the samples in furnace at 550°C for 2 hrs and water quenching T-4.	The microhardness hardness dramatically decreased as rotation speed increased.
10	Jeong-Ung Park et. al.	EH 47 steel	25 mm	50 to 2000 rpm	60 to 300 mm/min	Post weld treatment friction stir processing (FSP).	The fatigue life was increased by about 42%.

11	R.W. Fonda et al	AA 2195	25 mm	180	1.7 mm/s	Immediately pouring of water and Cool the plate.	Onion rings were observed in the weld nugget of spacing 0.58 mm.
12	L.M. Marzoli et al	AA6061/ $Al0_3$/20p	7 mm	100,200, 300,400, 500,600, 700 & 800 rpm	50,100, 150,200, 250,300, 350,400 mm/ min	T-6	Tensile strength achieved was 234 MPa. The failure of the sample was out of stir zone.
13	L. Ceschini et al	7005 (Al-Zn-Mg)	7 mm	600 rpm	300 mm/ min	T-6	The microhardness was similar as base material. The TMAZ's hardness was increased.
14	A. Barcellona et al	AA 2024 & AA 7075	3 mm	1040 rpm	104 mm/ min	T-4, cooling in water, natural aging, T-6.	In TMAZ, a decrease in the material micro-hardness values is attained.
15	P.M.G.PM oreira, et al	AA 6061 & AA 6082 -	3 mm	1120 rpm	224 mm/ min	T-6 obtained with artificial aging.	Tensile strength 231 MPa. The weld edge line is where the failure happened.
16	T. Saeid et al	2205 duplex stainless steel	2 mm	600 rpm	50,100, 150,200 & 250 mm/min	Introduction of Ar shielding gas.	The groove-like flaw was observed during the process.
17	Olivier Lorrain et al	Al alloy 7020	4 mm	100,500 &900 rpm	0.17,0.3 3,0.56, 08 & 1mm/ tu rn	T-6 rolled plates.	The characteristics of material flow using unthreaded tools are identical to those of material flow using traditional threaded tools.
18	P. Prasanna et al	AA 6061 Al alloy	5 mm	1200 rpm	14 mm/ min	Annealing and normalizing.	Maximum tensile strength 210 MPa. Tensile strength 90% of base material by annealing.
19	M. Thoma et al	Die cast alloys Al &Mg	3.3 mm	-	-	Ultrasonic application.	Increased tensile strength 25%. Three times higher number of cycles. The corrosive attack had an impact on the welding zone.
20	Sunil Sinhmar et al	AA7039	5 mm	1025 rpm	75 mm/ min	Multi-pass FSW.	Increase ductility from 13.5% to 23.6% without negatively affecting UTS.
21	Jinmyun Jo	Al 6061	6 mm	1200 rpm	4.5 mm/ min	Preheating	The least amount of bending and distortion was seen during welding.
22	Dwight Burford et al	7075 & 2042 alloy	-	-	-	Post welded aging	Temper T-81 and Temper T 73 were more stable in formation of precipitate morphology.

23	D. Muruganan dam et. al.	Al alloy 2024 & 7075	5 mm	600 rpm	30 mm/ min	Post weld heat treatment T-6 at 500°C, 1/2, 1,2,4,6 hrs.	Better weldment is the outcome of improved grain structure. After heat treatment, about 50% of joints exhibited fracture strain.
24	M.A. Tashkandi et. al.	6061 Al alloy	6 mm	760, 1120 & 1300 rpm	1 & 1.5 mm/s	Adding alumina particles by volume 2, 4, 6, 8, 10%.	As the volume proportion of alumina particles rose, the toughness of the welded joints also increased.

CONCLUSIONS

Mechanical powder mixing & hot isostatic pressing followed by forged composite solution heat treated (T-4 temper) material shows slightly lower hardness in TMAZ than weld nugget. Introduction Ar gas while FSW shows improved mean hardness value and the tensile strength of the weld joint. The annealing and normalising process uniformly distributed strengthening precipitates. By applying T-3, T-4, T-5 & T-6 heat treatments to FSW materials, we can improve the mechanical characteristics and joints resistance. In T-5 condition the hardness in stir zone slight increase at lower rpm. T-6 heat treatment with artificial aging shows better results; with comparable hardness, tensile strength, fatigue resistance with that of base material. T-6 treatment can be used where corrosion resistance is not concern. Effect of isothermal ageing was to decrease the hardness in the weld region. The preheating by HPDL will cause a reduction in tool wear. T73 can improve the stress corrosion cracking resistance. In partially recrystallized aluminium 5052 alloy plates, the specimens showed ductile mode of fracture. By the ultrasonic application increased tensile strength 25% and three times higher number of that normal process. It has more uniform distribution of hardness and having less area of HAZ. The US-FSW treatment is more suitable as it can done in single setting; so it can reduce the time and cost of the FSW process.

REFERENCES

1. Y.S. Sato, Y. Kurihara, S.H.C. Park and N. Tusji “Friction stir welding of ultrafine grained Al alloy 1100 produced by accumulative roll-bonding”, Elsevier ltd- Scripta Materialia, 50, 2004, pp. 57-60.

2. Huseyin Uzun, “Friction stir welding of SiC particulate reinforced AA2124 aluminium alloy matrix composite”, Elsevier ltd- Materials and design, 28, 2007, pp. 1440-1446.

3. P. Vijaya Kumar, G. Madhusudan Reddy, K. Srinivasa Rao, “Effect of post weld heat treatment on mechanical and stress corrosion cracking behaviour of AA7075 friction stir welding”, International journal of u-and-e-service, science and technology, vol.7, No 4, 2014, pp. 251-262.

4. ELISEEV Alexander, TARASOV Sergei, FORTUNA Sergei, RUBTSOV Valery, KALASHNIKOVA Tatiana, “Effect of ultrasonic application during friction stir welding on microstructure and properties of AA2024 fixed joints”, Key engineering materials Vol. 683, 2016, pp. 227-231.

5. S.K. Nirgude, C.M. Choudhari, S.D. Kalpande, “A Review on Pre/Post Treatments Used in Friction Stir Welding”, International conference on Advances in Thermal System, Materials and Design Engineering (ATSMDE-2017) proceeding, MM_42, pp.55 VJTI, Mumbai, India.

6. S.Y. Tarasov, V.E. Rubtsov, S.V. Fortuna, A.A. Eliseev, A.V. Chumaevsky, “Ultrasonic-assisted aging in friction stir welding on Al-Cu-Li-Mg aluminium alloy”, International institute of welding, Springer, 2017.

7. Masoud Jabbari, “ Effect of the preheating temperature on process time in friction stir welding of Al 606-T6”, Journal of Engineering, Hindawi Publication corporation, Volume 2013, Article Id- 580805,pp. 1-6.

8. B. Malard, F.De. Geuser, A. Deschamps, “Microstructure distribution in an AA 2050 T34 friction stir weld and its evolution during post-welding heat treatment.”, OATAO, Id- 16698, 2016.

9. N.T. Kumbhar, G.K. Day and K. Bhanumurthy, “ Friction stir welding of Aluminium Alloy”, BARC Newsletter, Issue No-321, July-August 2011, pp.11-17.

10. Mostafa. S.S. El-Deeb, S.A. Khodir, Sayed A. Abdalah, A.M. Gaafer and T.S. Mahmoud, " Effect of friction stir welding process parameters and post-weld heat treatment on the microstructure and mechanical properties of AA 6061-O aluminum alloys", Journal of American Science 2016, 12 (11),pp. 106-115.

11. Jeong-Ung Park, GyuBeak An, Heung-ju Kim, Jaehyouk Choi, "Development of Fatigue life improvement technology of but joints using friction stir processing", Hindawi Publication Corporatio, Advances in Mechanical Engineering, Volume 2014, Article Id- 943476, pp. 1-14.

12. R.W. Fonda, J.F. Bingeret, K.J. colligan, "Development of grain structure during friction stir welding" Elsevier ltd- Scripta Materialia, 51, 2004, pp. 243-248.

13. L.M. Marzoli, A.V. Strombeck, J.F. Dos Santos, C. Gambaro, L.M. Volpone "Friction stir welding of AA6061/Al_2O_3/20p reinforced alloy", Elsevier ltd-Composites science and technology, 66,2006, pp. 363-371.

14. L. Ceschini, I. Boromei, G. Minak, A. Morari, F. Tarterini, "Effect of friction stir welding on microstructure, tensile and fatigue properties of the AA7005/10 vol. % Al_2O_3 composite" Elsevier ltd-Composites science and technology, 67, 2007, pp. 605-615.

15. A. Barcellona, G. Buffa, L. Fratini, D. Palmeri, "On microstructural phenomena occurring in friction stir welding of aluminium alloys", Elsevier ltd- Journal of materials processing technology, 177, 2006, pp. 340-343.

16. P.M.G.P. Moreira, T. Santos, S.M.O. Tavares, V. Richter-Trummer, P Vilaca, P.M.S.T. De Castro, "Mechanical and metallurgical characterization of friction stir welding joints of AA6061-T6 with AA6082-T6", Elsevier ltd- Materials and design, 30, 2009, pp. 180-187.

17. T. Saeid, A.Abdollah-Zadeh, H.Assadi, F. Malek Ghaini, "Effect of friction stir welding speed on the microstructure and mechanical properties of a duplex stainless steel", Elsevier ltd-Materials science and engineering, A496, 2008, pp.262-268.

18. Olivier Lorrain, Veronique Favier, Hamid Zahrouni, Didier

19. Lawrjaniec, "Understanding the material flow path of friction stir welding process using unthreaded tools", Elsevier ltd-Journal of materials processing technology, 210, 2010, pp. 603-609.

20. P. Prasanna, Dr. Ch. Penchalayya, Dr. D. Anandamohana Rao, "Effect of tool pin profiles and heat treatment process in the friction stir welding of AA6061 aluminium alloy", Americal journal of engineering research,(IJER), e-ISSN-2320-0847, Volume 2, Issue 1, pp.7-15.

21. M. Thoma, G. Wagner, B. Strab, C. Conrad, B. Wolter, S. Benfer,

22. W. Furbeth, "Recent developments for ultrasonic-assisted friction stir welding: Joining, testing, corrosion-an overview", IOP conference series, Materials science and engineering 118, 2016, 012014, pp.1-7.

23. Sunil Sinhmar, Dheerendra K. Dwivedi, Vivek Pancholi, "Friction stir processing of AA7039 alloy", International conference on production and mechanical engineering, Dec.30-31, 2014, Bangkok, Thailand, pp. 75-78.

24. Jinmyun Jo, "Preheating effect on friction stir welding", Spring 2016, Mid-Atlantic ASEE conference, April 8-9, 2016, GWU

25. Dwight Burford, Christain Widener, Bryan Tweedy, "Advances in friction stir welding for aerospace application", American institute of aeronautics and astronautics, pp. 1-14.

26. D. Muruganandam, D. Raguraman, L.A. Kumaraswamidhas, " Effect of post-welding heat treatment on mechanical properties of butt joints in high strength aluminium alloys", Indian journal of engineering & material science, Vol. 22, 2015, pp. 381-388.

27. M.A. Tashkandi, J.A. Al-Jarrah, M. Ibrahim, " Increasing of the mechanical properties of friction stir welded joints of 6061 aluminium alloy by introducing alumina particles", Advances in materials science, vol. 17, No 2, 52, June 2017, pp. 29-40.

28. B. Baker, T. McNelley, M. Matthews, M. rotter, A. Rubenchik, S. Wu, " Use of high-power diode laser arrays for pre-and post-weld hating during friction stir welding of steels", Friction stir welding VII, TMS(The

mineral, metals and materials sosociety), 2015,pp. 21-36.

29. W. Boonchouytan, T. Tatanawilai, P. Muangjunburee, "Effect of pre/post heat treatment on the friction stir welded SSM 356 aluminium alloy", Elsevier ltd-Procedia engineering, 32, 2012 pp. 1139-1146.

30. S.K. Nirgude and S.D. Kalpande, " A review on pre/post

31. treatments used in friction stir welding" International conference on Advances in Thermal Systems, Materials and Design Engineering (ATSMDE) 2017.

32. Nirgude S. and Kalpande S., "Parametric optimization of friction stir welding of AA 6101 T-64 and pure Cu using response surface methodology", International Journal on Interactive Design and Manufacturing (IJIDeM),1-19, (2023).

Thermal Analysis of Engine Fins with Different Types of Notches and Materials

Bhavna Walde*
✉ missbv20899@gmail.com

Bhupendara
✉ bhoobhookoshale@gmail.com

Chandra Prakash
✉ chandrasahu9256@gmail.com

Krishna Gahir
✉ krishnagahir7@gmail.com

Chandra Prakash Dewangan*
✉ cdewangan147@gmail.com

Department of Mechanical Engineering
Government Engineering College
Raipur, Chhattisgarh

ABSTRACT

Engine fins are designed to enhance the cooling efficiency of an engine by increasing the surface area exposed to airflow. Their primary function is to dissipate heat generated during operation, thereby preventing overheating and ensuring optimal performance and longevity of the engine or device. These fins are usually made of metal, such as aluminum or copper due to their excellent thermal conductive properties [1]. This paper deals with the thermal performance of engine fins with the putting of different types of notches such as rectangular and triangular are made up of aluminum al6063 and aluminum nitride escorted by deviating thermal conductivity was examined by using ANSYS [1,2]. By creating three dimensional geometries analyzed with ANSYS WORKBENCH 2024 R1 to obtain the best possible geometries with notch and material for the fins. Notches in engine fins serve several purposes such as increased surface area, enhanced air flow for more efficient heat dissipation [2]. The core objective of this paper is centered on elevating the heat transfer rate within automobile engines to meticulously selecting the most suitable materials and fin geometries for the cooling fins. We aspire to improve engine performance, efficiency, and reliability. Ultimately contributing to advancements in automotive technology.

KEYWORDS *: Notches, Heat flux, Thermal conductivity, Cooling efficiency, Ansys workbench, ANSYS2024 R1.*

INTRODUCTION

Heat transfer by engines is a fundamental aspect of thermodynamics and mechanical engineering, playing a vital role in various industrial and technological applications. Engines are devices designed to convert thermal energy into mechanical work, with heat transfer being the driving force behind this conversion process. Understanding the principles of heat transfer in engines is essential for optimizing their efficiency, performance, and environmental impact.

One of the key challenges in engine design is managing heat transfer to maximize efficiency while minimizing losses. Heat is transferred through a variety of mechanisms, one of which is conduction. including conduction, convection, and radiation, each of which presents unique range of techniques and technologies, such as insulation, cooling systems, and heat exchangers, to control and optimize heat transfer within engines [2].

The heat must be effectively managed to prevent the engine from overheating, which can lead to reduced performance, damage to components, and even engine failure. Engine fins are specifically designed for motive to enhance the heat transfer and provides cooling effect during engine operation and overheating conditions. It's increasing the engine's surface area.

The heat transfer process in an internal combustion (IC) engine is vital for regulating temperatures and ensuring efficient operation. Heat transfer is a complex process involving several methods primarily Conduction is the transfer of heat through solid materials. Each configuration of shape, size, and material inherently offers its unique efficiency. Hence, the process of selection aims at identifying the most optimal combination that ensures the highest efficiency, consequently achieving the required heat transfer rate for optimal engine performance. Implementing extended surface areas on cylinder surfaces serves the purpose of augmenting the contact area with the fluid flow, thereby enhancing heat transfer efficiency [1, 4].

The core purpose of engine fins lies in dispersing the heat emanating from the engine. By build on a notch or notch-like features, airflow around the fins is enhanced and most significant to better heat dissipation Engine Cylinder Fins with varied Geometry and Material. Our primary focus lies in dissecting the thermal properties through alterations in the geometry, material composition, and thickness of cylinder fins [5]. Additionally, the notch can also contribute to reducing the weight of the fins without compromising their structural integrity, which can be advantageous in applications where weight is an essential aspect, especially within the aerospace or automotive sectors. Engine fins are specially designed for to improve the cooling, heat transfer efficiency, optimal performance of overall automobile engine [1, 5].

LITERATURE REVIEWS

For achieving main significance of objective to enhance the heat dissipation and improve cooling efficiency from engine by modification of engine fins with different shapes and material were analyzed in the past and recent year are following ways:

Aman lahre et al.[2023]. This project's methodology compares the heat transfer of engine fins made of various materials under steady state conditions in order to determine the best material and fin geometry for improving thermal management and engine performance. [1].

K. Satishkumar et al. [2017]. It was researched to computational analysis of heat transfer through fins with different types of notches. In this study to investigate flow and heat transfer rate in automobile fins by analyzing and creating the 3D modelling in ANSYS-CFD fluent software [2].

Rajat Kumar et al. [2020]. In this paper studied about the static thermal analysis of fins models using ANSYS. The project focuses on enhancing the thermal properties of engine fins by utilizing wind flow to increase the heat dissipation rate. This is achieved by implementing principles that optimize the geometry, material, and design of the fins. The main aim of the study is to improve heat transfer efficiency and overall thermal performance [3].

G. Babu and M. Lava Kumar [2013]. The project researched on Heat Transfer Analysis and Optimization of Engine Cylinder Fins of Varying Geometry and Material," focused on conducting analyses and refining optimization strategies. For the heat transfer characteristics of engine cylinder fins through modifications in geometry and material composition [4].

METHODOLOGY

The methodology presented herein details the process for conducting a thermal analysis of engine fins using ANSYS software. The aim of this research is to explore the phenomenon of heat transfer characteristics of engine fins under various notches, geometries and materials at operating conditions. By employing ANSYS's powerful computational tools, our aim to optimize the design of engine fin to enhance heat dissipation efficiency and improve overall thermal performance. In this study we followed given flow chart below which shows basic designing process.

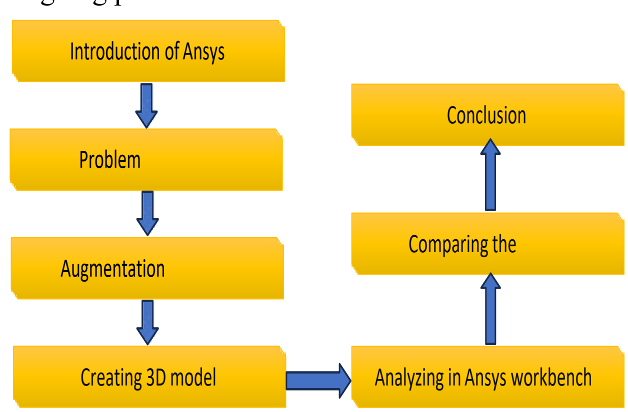

Fig. 1 Methodology

Initially, we began our effort by collecting the necessary datasets related to the analysis and modeling of cooling fins. Thorough the examination of several review papers, we gained knowledge on the design processes and underlying mechanisms. Next, leveraging the capabilities of Ansys, we conducted a comprehensive analysis, which yielded conclusive results.

Geometries and material properties

ANSYS is a leading engineering simulation software suite utilized extensively in various industries to perform virtual prototyping, design validation, and performance analysis. The design process for the cooling fins involves utilizing ANSYS software. For this particular project, we have opted to focus on a 100 CC automobile engine for which the cooling fins are being designed. In analysis, we have chosen aluminum nitride and aluminum alloy 6063 as the material of choice. Regarding the design specifics, we are exploring the incorporation of three distinct types of notches. These notches serve as critical features in our design analysis, contributing significantly to the overall performance and efficiency of the cooling fins. They are as follows: 1. Rectangular Fin without Notch 2. Fin with Rectangular Notch 3. Fin with Triangular Notch 4. Fin with Circular Notch

Fig: 2 Rectangular Fin without Notch

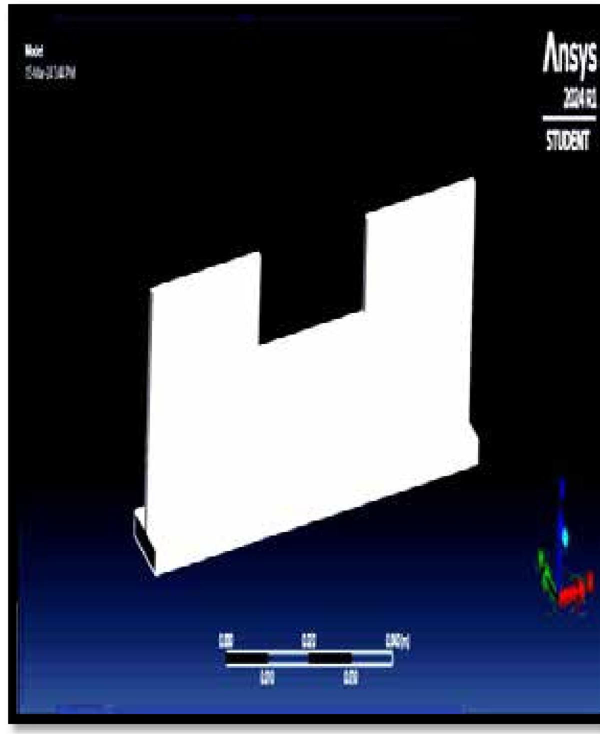

Fig: 3 Fin with Rectangular Notch

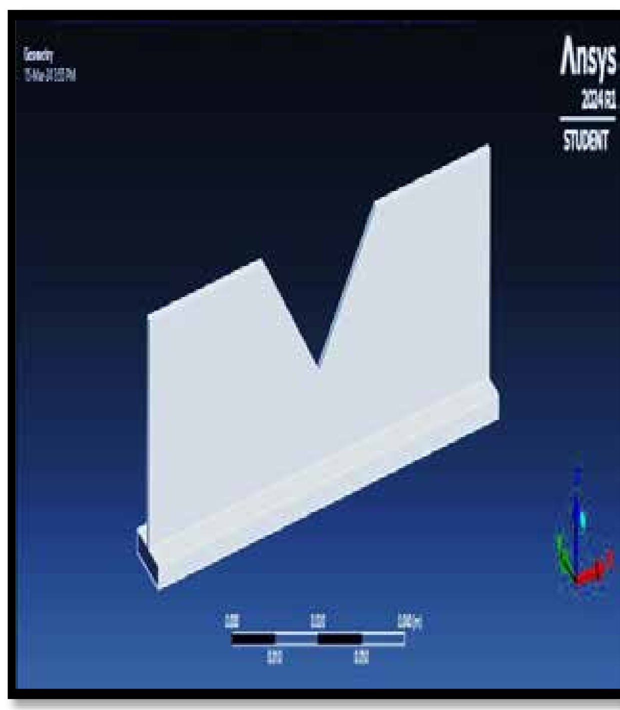

Fig: 4 Fin with Triangular Notch

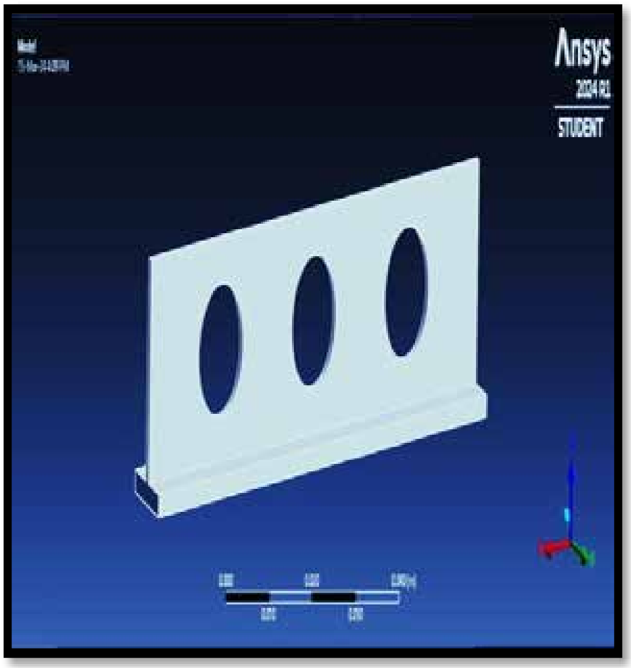

Fig: 5 Fin with Circular Notch

Properties of Aluminum alloy (6063) and Aluminum Nitride

Table 1. Material Data of the Aluminum al.6063

Physical and Thermal Properties of Al alloy (6063)	Value
Thermal Conductivity	210 W/m-k
Modulus of Elasticity	68.9 GPA
Melting Point	600°C
Density	2.70 g/cm^3
Poisson's ratio	0.33

Table 2. Material Data of the Aluminum Nitride

Physical and Thermal Properties of AIN	Value
Thermal Conductivity	321 W/m-k
Modulus of Elasticity	310 GPA
Melting Point	2500°C
Density	3.26g/cm^3
Poisson' s ratio	0.25

3D Modelling of Fins

In this study we have created Three-dimensional model through Ansys. Fins model designed with the material selection aluminium alloy 6063 and aluminium Nitride. One of the common Mechanism We focused on the heat transfer performance by putting of three types geometries such as Rectangular, Triangular and Circular shaped fins with notches. Ansys Workbench was used to assess the results of a thermal simulation that was carried out using a computational fluid dynamics (CFD) software program.

The engine block's coolant flow process, which transfers heat from the engine to the fins, is the basis for the simulation. The heat will then be released by the fins into the surrounding air, and the simulation will determine how hot the engine blocks and fins are overall.

- Dimensions of the fin model

  Length of Fins = 90 mm

  Width of Fins = 20 mm

  Thickness of Fins = 1 mm

- Implementing boundary conditions under steady-state conditions

  Convection conditions = 25°C

  Ambient Temperature = 25°C

  Film Coefficient = 25w/m2k

Comparative Analysis of Result in Ansys workbench

Through thorough comparison, certain fin designs may exhibit superior heat dissipation capabilities, characterized by more even temperature distribution across the engine block.

In conducting the analysis, we operate within a steady-state condition, a state where temperature remains constant over time. This condition signifies a balance where heat transfers into and out of the system reaches equilibrium, resulting in no observable change in temperature. By examining the system under these conditions, we can accurately assess the thermal behavior of the engine fins without the influence of transient effects. Temperature variations in different geometries are shown below.

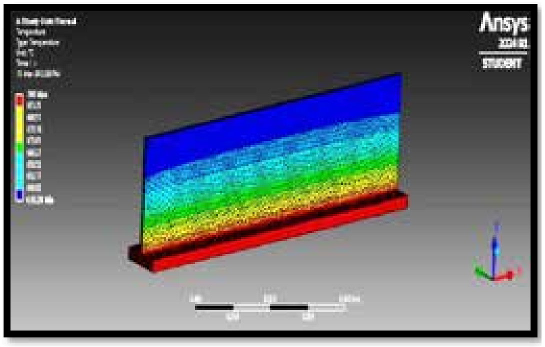

Fig: 6 Temperatures in Conventional Fin

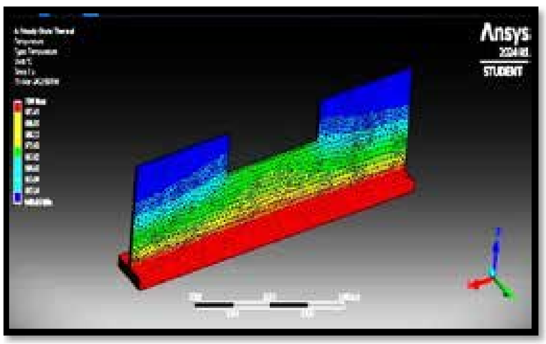

Fig: 7 Temperatures in Rectangular Fin

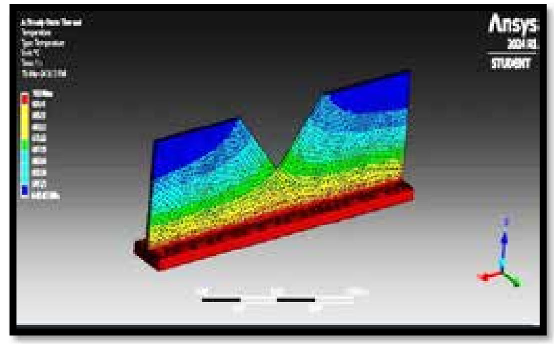

Fig: 8 Temperature in Triangular Fin

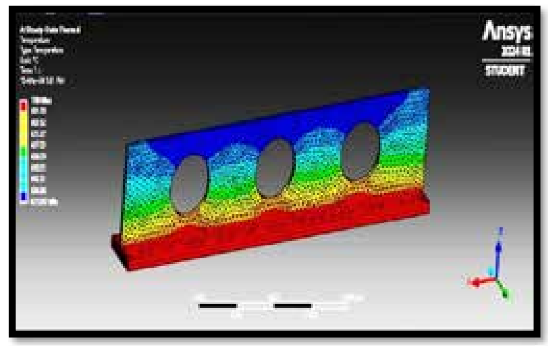

Fig: 9 Temperature in Circular Fin

Table 3. Maximum and Minimum Temperatures of materials

Examining Heat Transfer Characteristics of Engine Fins with Varied Materials and Notch Configurations under Steady State Conditions:

Materials	Notches	Temperature (^{o}C)		Heat Flux(W/m^2)	
		Maximum	Minimum	Maximum	Minimum
Aluminium Nitride	Without notch	700	639.28	6.8928e5	15402
	Rectangular Notch	700	640.65	6.6416e5	15434
	Triangular Notch	700	640.55	6.6416e5	156985
	Circular Notch	700	625.82	7.0539e5	44507
Aluminium alloy (6063)	Without notch	700	664.28	7.0773e5	16006
	Rectangular Notch	700	665.02	6.8931e5	15500
	Rectangular Notch	700	665.02	6.6417e5	15671
	Circular Notch	700	655.91	7.3474e5	42111

Comparison of all three types of Fins with Conventional Fins

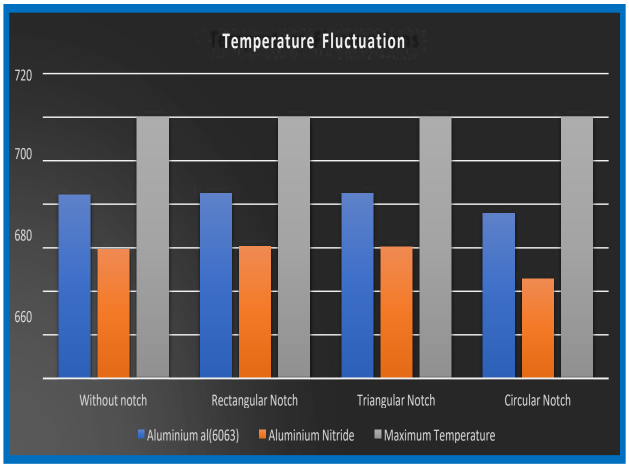

Fig: 10 Temperature fluctuations of different materials and geometries

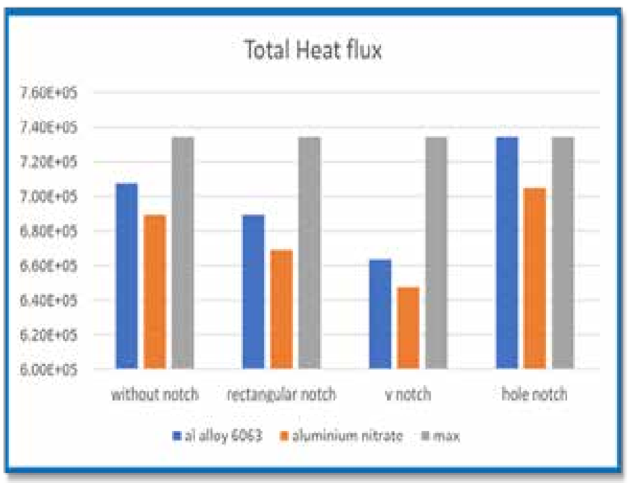

Fig: 11 Total Heat flux of different materials & geometries

RESULT

Through this comprehensive analysis, we have derived insightful findings by comparing various notches and materials concerning heat transfer. Among the tested notches, it was evident that the Circular notch, when integrated into the conventional fin design, exhibited superior performance in terms of temperature reduction. After the comparison, we scrutinized the performance of two distinct materials are aluminium alloy 6063 and aluminium nitride. In the absence of any notch, the conventional fin geometry showcased a significant temperature drop when fabricated from aluminium nitride, surpassing the performance of aluminium alloy 6063.

CONCLUSION

The present study deals with optimizing heat dissipation within engine fins using ANSYS software. Different materials with various fin geometries, including rectangular, triangular, and circular notches were simulated. The result reveals that aluminium alloy 6063 and aluminium nitride both have higher thermal conductivity. By this analysis we found that the circular notch configuration. This particular geometry showcased superior heat transfer properties, making it exceptionally adept for the cooling requirements of automobile engines. All the above comparison shows that Aluminium Nitride with circular notch is better in heat dissipation than conventional fin material.

REFERENCES

1. Aman Lahre, Snehlata Kanwar, Merkhapunp Bara, Manisha Usendi, Chandra Prakash Dewangan, “Comparative Analysis of Heat Transfer of Engine Fins with different Materials in Steady State Condition” in Journal of Thermal and Fluid Science Volume 4, Issue 1, June 2023, pp 40-45.
2. K. Sathishkumar, K. Vignesh, N. Ugesh, P. B. Sanjeevaprasath, S. Balamurugan, “Computational Analysis of Heat Transfer through Fins with Different Types of Notches” in International Journal of Advanced Engineering Research and Science (IJAERS), Volume-4, Issue-2 (Feb. - 2017).
3. Rajat Kumar, Devendra Singh, Ajay Kumar Sharma, “STATIC THERMAL ANALYSIS OF FINS MODELS USING ANSYS” in International Journal of Mechanical Engineering and Technology (IJMET) Volume 11, Issue 2, February 2020, pp. 10-21.
4. G. Babu, M. Lava kumar, Heat Transfer Analysis and Optimization of Engine Cylinder Fins of Varying Geometry and Material in IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), Volume-7, Issue-4 (Jul. - Aug. 2013), PP 24-29.
5. Kota Leela Sai Bharath, V Pradeep Kumar, “Design and Analysis of a Rectangular Fin with Comparing by Varying Its Geometry and Material”, With Perforation

and Extension in 2021 Turkish Journal of Computer and Mathematics Education (TURCOMAT), 12(2), 3039– 3050.

6. Mr. K. Manikandan, S. Thirumoorthi, S. J. Sabharinaathan, R. Sugumar and P. Sabareswaran, “Design and Analysis of Fins Using Various Configuration” in International Journal of Advanced Research in Science, Communication and Technology (IJARSCT) Volume 4, Issue 2, April 2021.

7. K. Karthikeyan, C. Saravanan, T. Senthil Kumar, “Enhancement of Heat Transfer Analysis and Optimization of Engine Fins of Varying Geometry”, International Journal of Trend in Scientific Research and Development”, Volume - 2, Issue – 4, 2018.

8. N. Srinivasa Rao1, G.V. Subhash2, K. Ashok Kumar, “Design and Study the Effectiveness of Engine Cylinder Fin with Variable Geometry and Material”, International Journal of Research in Engineering and Technology, Volume: 05, Issue: 10, 2016.

Optimization of Micro Drilling of CFRP-Titanium Alloy Hybrid Material by using Response Surface Methodology

Jitendra Acharya
Hrishikesh Bhave
Department of Mechanical Engineering
VPMs' MPCOE
Velneshwar, Maharashtra
✉ jitendra.acharya@vpmmpcoe.org

Omkar Jarali
Department of Mechanical Engineering
GF's GIT
Lavel, Maharashtra

Jitesh Bhagat, Vinayak Wale
Department of Mechanical Engineering
G M Vedak Institute of Technology
Tala, Maharashtra

ABSTRACT

n this study, radial over cut in the mechanically micro drilling process for CFRP-Titanium alloy stacked hybrid is estimated using the response surface approach. Spindle rate, feed rate, and Minimum Quantity Lubrication flow velocity are employed as inputs parameters to look into the radial overcut. To plan the testing, the CCD method was employed. A mathematical model was constructed after 20 tests to link the impacts of various machining factors with radial overcut. ANOVA at the 5% level of significance yielded the significant coefficients. Based on the data, it was discovered that spindle speed has a substantial influence on radial over cut. The projected findings based entirely on established models are found to be in good connection with the expected values, with the coefficient of determination 0.7482 for radial overcut fitting the experimental data relatively well.

KEYWORDS *: Mechanical micro drilling, Central composite design, Radial overcut, CFRP/Ti6Al4V, Response surface methodology.*

INTRODUCTION

Mechanical micro drilling is capable of producing minute holes as long as the tool's surface is tougher than the workpiece. This method involves repeatedly inserting and removing the drill from the hole, which creates a hole. The technique's potential may be seen in its ability to drill holes as small as 50 micrometres in metals, plastics, and polymers. Drill bits are used to cut holes in soft metals such as brass and copper. These drill bits are made of high-speed steel, tungsten, and other hard materials. Because more tiny and micro gadgets are being used, there is a growing demand for micro drilling, or creating holes that are smaller than 1 mm in diameter miniature drilling is most commonly used in the automotive, aeronautics, electronics, and therapeutic domains. [1-5]

Several studies looked on mechanical micro-drilling of challenging materials. According to a study by R Landge et al., mechanical micro-drilling of brass material was evaluated experimentally using speed, feed, hole depth, and machining time as input parameters. The mathematical modelling for the material removal rate response were developed using response surface techniques. [6-7]

In order to create, enhance, and optimise processes, the Response Surface Methodology (RSM) combines several input parameters and analyses how their intricate connections effect the performance of the output variables as a whole. [10-11]. RSM creates the version utilising a statistical layout of test techniques, such the CCD, and then mounts ANOVA checks to measure the performance of the recommended model. To observe how input parameters impact responses, 3D output graphs can be employed. The RSM technique has been used extensively in studies to assess the effectiveness of industrial processes. [8-9], [12-13] The literature study found no published research on the micro-drilling of CFRP-Titanium hybrid material. In order to produce a mathematical radial overcut using input parameters, the response surface technique is used in this study. The suitability of the developed model was assessed using an ANOVA test, and the impact of input parameters on radial overcut was investigated via 3D response graphs.

METHODOLOGY & EXPERIMENTAL WORK

The studies were carried out on, SMD10B CNC micro drilling machine. The machine's spindle has a capability of 6001 rpm to 60000 rpm. Lubricant oil was a brown transparent emulsified oil. CFRP and Ti6Al4V grade 5 workpieces were employed in the trials. CFRP and Ti6Al4V were stacked using Araldite AW134 Epoxy resin. Solid carbide (coating thickness 0.2 micron) was employed for the current investigation. For the purposes of this investigation, a micro drill with a diameter of 0.4 mm and a point angle of 135 degrees was used.

$$Radialovercut = \frac{d_{jt} - d_t}{2} \quad (1)$$

Here, dt denotes the tool's diameter whereas djt denotes the size of the hole after machining.

The RSM which investigates how the performance of the response variables is influenced by the extensive interconnections of the input variables, is an excellent tool for building, improving, and optimising processes. The response surface is often characterised by the following equation [14]:

$$Y = \beta_0 + \sum_{i=1}^{s} \beta_i \chi_i + \sum_{i=1}^{s} \beta_i \chi_i + \sum_{i=1}^{s} \beta_{ii} \chi_i^2 + \sum_{i=j}^{s} \beta_{ij} \chi_i \chi_j + \varepsilon \quad (2)$$

Using statistical analysis of experiments techniques like the CCD, RSM develops the model and then employs ANOVA tests to evaluate the suggested model's efficacy. The CCD technique, a type of experimental design, was used to construct the trials. Using the statistical program Design Expert 13.0, one can determine the regression model's coefficients based on the experiment's findings.

Table 1. Central Composite Design & Results

	Factors			Response
Run	Spindle speed	Feed rate	:MQL flow rate	Radial overcut
	RPM	mm/min	ml/hr	
1	30000	1.2	150	3.45
2	40000	1.2	150	28.24
3	30000	1.7	150	12.6
4	40000	1.7	150	15.7
5	30000	1.2	300	9.21
6	40000	1.2	300	11.13
7	30000	1.7	300	17.6
8	40000	1.7	300	20.8
9	26591	1.45	225	3.35
10	43408	1.45	225	32.25
11	35000	1.02955	225	25.51
12	35000	1.87045	225	20.11
13	35000	1.45	98.8655	2.36
14	35000	1.45	351.134	7.21
15	35000	1.45	225	5.12
16	35000	1.45	225	11.56
17	35000	1.45	225	8.35
18	35000	1.45	225	0.11
19	35000	1.45	225	8.35
20	35000	1.45	225	19.56

EXPERIMENTAL RESULT AND DISCUSSION

Twenty experimental runs for the CCD were performed, according to the machining data in Table 1. As illustrated in Fig. 1, an optical microscope (ALICONA) may be used to measure the diameter of machined holes on work materials. The output response, or radial overcut, is then calculated for each run and reported in Table 1.

Fig.2 ALICONA optical microscope

Mathematical model for radial overcut and ANOVA

The DoE software and the pertinent data from Table 1 were used to create the mathematical model, which was used to relate how the machining settings affected the size of the radial overcut. The quality of fit of the model must be assessed before data analysis may proceed. The tests for the regression model's significance, the significance of the model coefficients, and the test for poor fit are all a part of the model adequacy checking. ANOVA is used to achieve this goal. The quadratic model is statistically significant for radial overcut analysis, according to the fit summary. ANOVA Table 5 presents the findings of the quadratic model for radial overcut.

The model appears remarkable based on its Model F-value of 3.30. Just 0.01% of the time may noise cause a "Model F-Value" of this size. Table 5's "Prob> F" values indicate that model terms with 95% confidence intervals less than 0.05 are significant. A, AB, and B2 were significant model variables in this situation. The model terms are not significant if the value is greater than 0.1000. If your model has many unnecessary words (apart from those necessary to maintain hierarchy), model reduction may help it.

The "Lack of Fit F-value" of 0.8510 indicates that there is no statistically significant difference between the Lack of Fit and the pure error. A "Lack of Fit F-value" this high might be due to noise with a 56.81% possibility. It also displays the R^2 and corrected R^2 values for the model. The better the response model matches the experimental data, the closer R2 is to unity. According to the calculated R-Squared value of 0.7482, the model explains around 74.82% of the ROC variance. A fair agreement can be drawn between the "Pred R^2" value of 0.4624 and the "Adj R^2 " value of 0.5215. Furthermore, the "Adeq Precision" score of 5.5638 for this model suggests a sufficient signal and is higher than 4. Utilise the design space's navigational tools.

Effect of input parameters on the radial overcut

Radial overcut, a key aspect of micro drilling, impacts precision. Figure 2 illustrates how spindle speed and feed rate affect it, with medium settings yielding minimum overcut. Figure 3 shows that lower MQL flow rates and mid spindle speeds result in the lowest overcut. Figure 4 indicates that optimal feed rates, MQL flow rates, and spindle speeds minimize overcut. Spindle speed affects overcut by influencing centrifugal force on lubricating fluid, while higher feed rates with increased spindle speed lead to greater friction and overcut due to heat and wear..

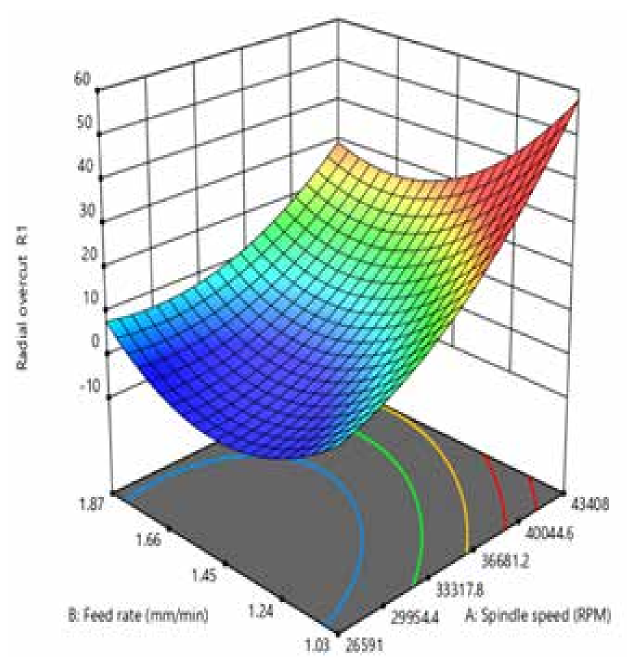

Fig. 2. RSM for radial overcut Vs spindle speed and feed rate

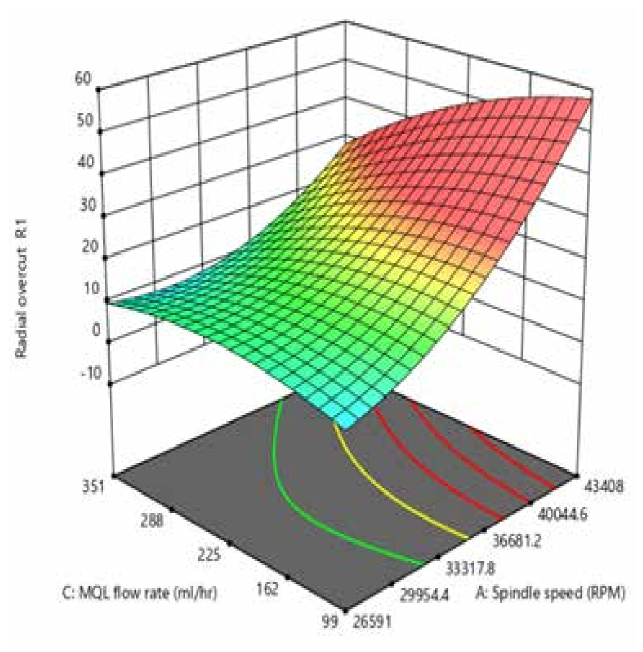

Fig. 3. RSM for radial overcut Vs spindle speed and MQL flow rate

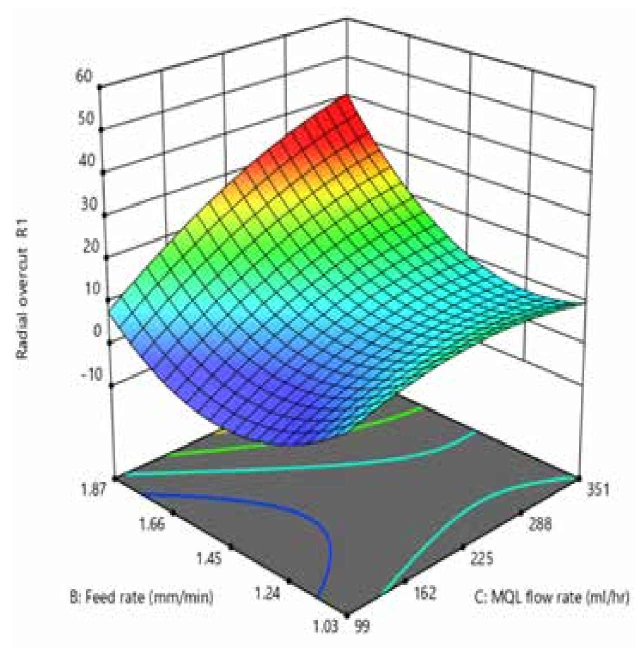

Fig. 4. RSM plot for radial overcut Vs feed rate and MQL flow rate

CONCLUSION

This study employs response surface methods to predict radial over cut in micro drilling of CFRP-Titanium alloy hybrid material. CCD is used for twenty tests across five levels of three input parameters. ANOVA analysis highlights spindle speed as highly significant, while rate of feed and Minimum Quantity of Lubrication flow rate are not. The mathematical model achieved a coefficient of determination of 0.7482, indicating good match with experimental data. Intermediate levels of spindle velocity and feed notably reduce radial over cut. This approach can be extended to model other machining parameters and reactions in the future.

REFERENCES

1. Jinyang Xu, Mohamed El Mansori. Experimental study on drilling mechanisms and strategies of hybrid CFRP/Ti stacks, Composite Structures 157 (2016) 461–482, Elsevier.
2. Isbilir, Ozden and Ghassemieh, Elaheh. (2013). Comparative study of tool life and hole quality in drilling of CFRP/titanium stack using coated carbide drill. Machining Science and Technology.
3. Islam Shyha, Sein Leung Soo, David K. Aspinwall, Sam Bradley, Stuart Dawson, Cornelius J. Pretorius, 2010, Drilling of Titanium/CFRP/Aluminium Stacks, Key Engineering Materials ISSN: 1662-9795, Vols. 447-448, pp 624-633.
4. Hasan, M., Zhao, J. and Jiang, Z. (2017). A review of modern advancements in micro drilling techniques. Journal of Manufacturing Processes, 29 343-375.
5. Heinemann, R., et al., The performance of small diameter twist drills in deep-hole drilling. Journal of manufacturing science and engineering, 2006. 128(4): p. 884-892.
6. R. landge, A. borade, 2017. Analysis of Micro-Drilling Process Using Response Surface Methodology., International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 20 (2017) pp. 9570-9574.
7. K Shunmugesh, K Pannerselvam, 2018. Multi purpose optimisation of micro drilling using taguchi technique based on membership function., Indian Journal of Engineering and Material science, pp. 383-390.
8. Djoudi, Aissani-Benissad, F., Bourouina-Bacha, 2007. Optimization of copper cementation process by iron using central composite design experiments. Chemical Engineering Journal 133, 1–6.
9. Gopalakannan, S., Senthilvelan, T., 2013. EDM of

cast Al/SiC metal matrix nanocomposites by applying response surface method. International Journal of Advance Manufacturing Technology 67, 485–493.

10. Lin, Y.C., Tsao, C.C., Hsu, C.Y., Hung, S.K., Wen, D.C., 2012. Evaluation of the characteristics of the micro electrical discharge machining process using response surface methodology based on the central composite design. International Journal of Advance Manufacturing Technology 62, 1013–1023.

11. Natarajan, U., Periyanan, P.R., Yang, S.H., 2011. Multiple-response optimization for micro-end milling process using response surface methodology. International Journal of Advance Manufacturing Technology 56, 177–185.

12. Sohani, M.S., Gaitonde, V.N., Siddeswarappa, B., Deshpande, A.S., 2009. Investigations into the effect of tool shapes with size factor consideration in sink electrical discharge machining (EDM) process. International Journal of Advance Manufacturing Technology 45, 1131–1145.

13. Tsao, C.C., 2008. Comparison between response surface methodology and radial basis function network for core-center drill in drilling composite materials. International Journal of Advance Manufacturing Technology 37, 1061–1068.

14. Sameh, S.Habib., 2009. Study of the parameters in electrical discharge machining through response surface methodology approach.Applied Mathematical Modelling 33, 4397–4407.

15. Veenaraja, D., Muthukumar, V., Venkatasamy, R., Dharmendhirakumar, M., Sureshbabu, A., Senthilkumar, N., 2013. “Impact of Machining Parameters on the EDM Process Responses: A Taguchi Approach for Al-SiC MMC,” 4th Nirma University International Conference on Engineering. Ahmedabad, India, paper#2251.

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